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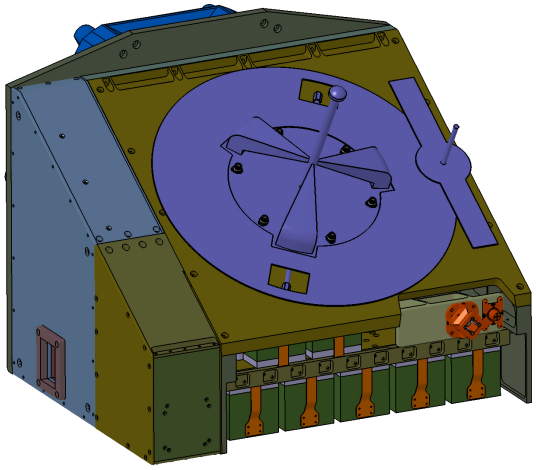
Title: NanoRacks External Platform (NREP) Standard Interface Definition Document



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7A	03/06/15	throughout 11.1.1.3 11.2.1.2	Company name change Data streaming (size limitation) Int. payload networking: DHCP not supported Various clarifications

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1 Introduction

1.1 Purpose

This Standard Interface Definition Document (SIDD) defines and controls the generic interfaces between the NanoRacks External Platform (NREP) and any payload. Each payload representative will have a specific Interface Control Agreement (ICA) which references all applicable requirements stated in this SIDD as well as any payload specific requirements that are not defined in this document. Upon placement of a contract, an initial payload ICA will be developed based upon the available payload data. Subsequent iterations will follow that will fully define all payload applicable requirements, services, and interfaces. The ICA also defines the technical responsibilities of NREP service provider, i.e., NanoRacks with Airbus DS Space Systems, and the payload representative.

1.2 Definitions

Certain terms used in this document have precise meanings that need to be emphasized. These particular terms, listed below, are used in a very narrow sense in order to provide commonality of usage and meaning.

1.2.1 NREP

“NREP" is defined as an External Payload Platform (ref fig-1-1) capable of accommodating internal ISS payload removal and replacement, transfer of integrated payload through ISS JEM Airlock to the JEM External Facility. The NREP will operate experiment payloads in the open space environment while attached to the JEM-EF.

1.2.1.1 NREP-P Baseplate

The NREP-P Baseplate (ref. Fig-1-2) is defined as the NREP – Payload interface to the NANORACKS External Platform. This interface will provide common attach interfaces to the payload, allowing a standardized mechanical, electrical, thermal, and data interface.

1.2.1.2 NREP-P

The NREP–Payload (NREP-P) (ref fig-1-3) is the experiment package developed by the user/customer. The nominal experiment package is a 4U Cubesat Form Factor (40cmx10cmx10cm), equipped with a standardized USB 2.0 interface, allowing for a plug-and-play interface. Other payload experiment packages can be accommodated per unique interface agreements.

1.2.1.3 Payload representative

The payload representative is the person or organization that represents a payload to the NREP service provider.

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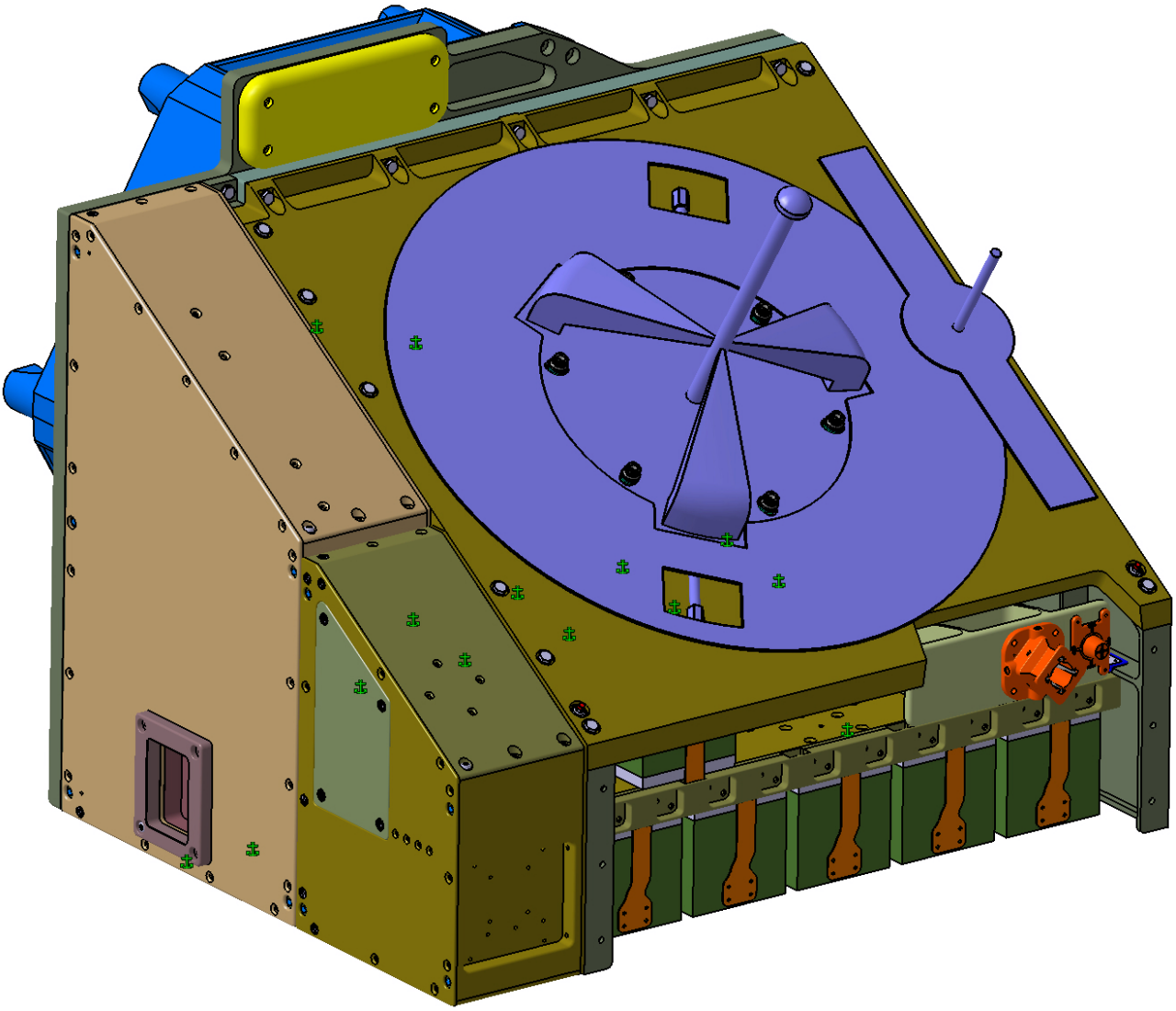

Figure 1-1: NREP

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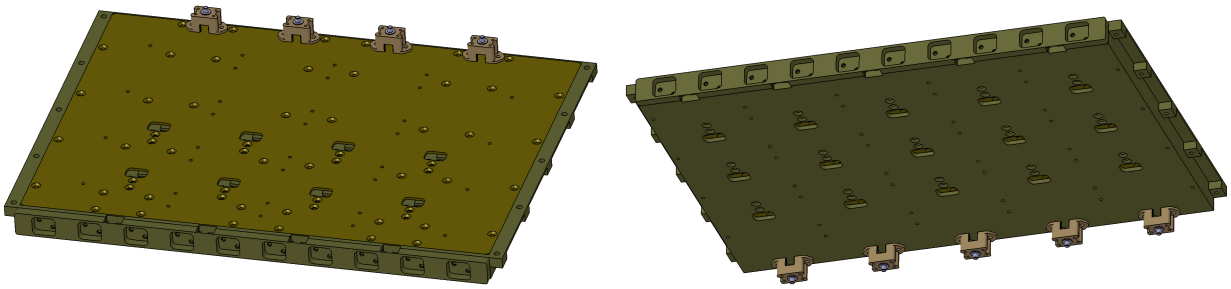

Figure 1-2: NREP-Baseplate

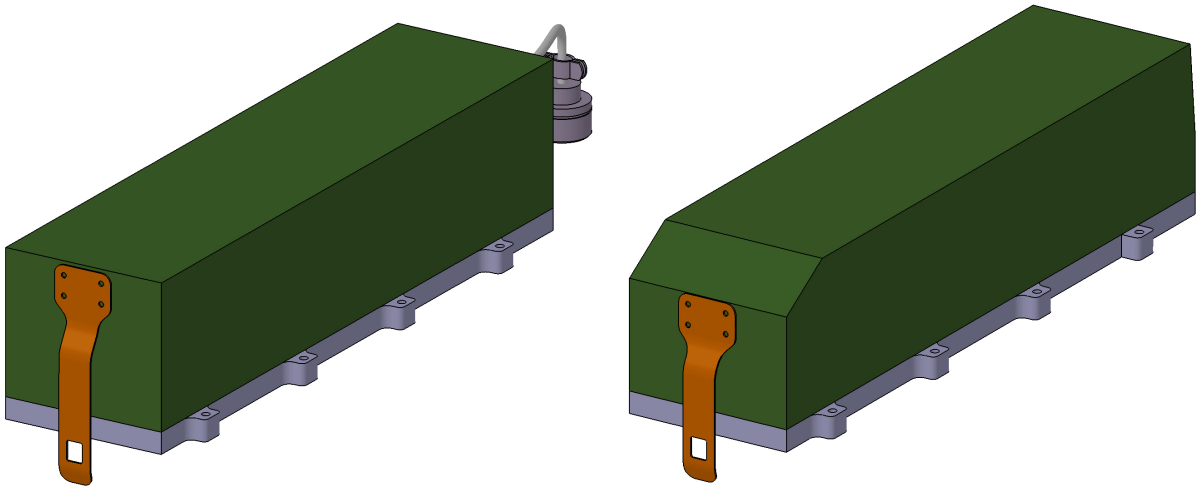

Figure 1-3: NREP-P

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1.3 Customer Support and Payload Manifesting

This phase starts with the first contact of payload provider and shall ensure that the payload can be accommodated and operated in the NREP ISS environment. At the end of the phase a decision will be made to proceed with the payload integration and operation.

Time to launch [m]	Activity	Remarks
N/A	Contact NREP Service Provider	
N/A	Compatibility Check of Payload to NREP and ISS requirements and Constraints	
L-15	Letter of Intent and Preparation of draft ICA Core Document	

1.4 Standard Payload Integration

The following schedule is valid for transport on SpaceX Dragon. In case of other launch vehicles TBD months need to be added to the time. Note: launch-minus dates are provided as template example for nominal 12 month processing. Unique agreements can be discussed as part of contracting negotiations.

Time to launch [m]	Activity	Remarks
L-12	Contract and ICA Core Baseline (signature) and Appendix Development	
L-10	NREP-P deliveries: — Functional Description — Interface Drawings — Material Identification and Usage List — Budget Report	
L-10	NREP service provider starts ISS safety process	
L-9	NREP-P delivery: Thermal Model or equivalent data	
L-9	Upload manifesting	
L-6	NREP-P delivery: Flight operations description	
L-3	NREP - P handover to NREP service provider	
L-3 to L-1	NREP-P Environmental tests and Functional test within NREP test bed	
L-1	NREP-P Certification for flight and handover to launch authority	

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1.5 Standard Payload Operation

Time from launch [m]	Activity	Remarks
L-0	Launch	
L+4	NREP-P installation into NREP	
L+4 to L+7	NREP -P operation	Standard duration, can be extended
L+13	NREP-P return to payload provider	Non standard service

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2 Documentation

2.1 Applicable Documents

The following documents shall form a part of this document to the extent specified herein. The revision/issue in effect on the contract agreement date is valid. In the event of conflict between the documents listed below and the contents of this document, the contents of this document shall govern.

2.1.1 NanoRacks External Payload Platform (EPP) Interface Control Document SSP 57781, Initial Release (Draft), 2013-04-01

2.1.2 NanoRack External Platform (NREP) Software Interface Control Document SSP 57322, Rev. B – Interim, March 2015

2.1.3 Contamination Control Requirements, JPG 5322.1 / SN-C-0005

2.1.4 JSC Fastener Integrity Testing Program, JSC 23642

2.1.5 Decal Process Document and Process, JSC 27260

2.1.6 Requirements for Submission of Data Needed for Toxicological Assessment of Chemicals and Biologicals to be Flown on Manned Spacecraft, JSC 27472

2.1.7 NanoRack External Platform (NREP) Interface Control Document – JEM-EF JX-ESPC-101094

2.1.8 Adhesive Bonding, MIL-HDBK-691

2.1.9 Materials Selection List for Space Hardware Systems, MSFC-HDBK-527

2.1.10 Structural Design and Test Factors of Safety for Spaceflight Hardware, NASA-STD-5001

2.1.11 Flammability, Odor, Offgassing, And Compatibility Requirements And Test Procedures For Materials In Environments That Support Combustion, NASA-STD-6001

2.1.12 General Specifications for Vacuum Stability Requirements of Polymeric Material for Spacecraft Applications, SP-R-0022A

2.1.13 Pressurized Payload Interface requirements Document, SSP 5700, Rev L

2.1.14 Space Station Requirements for Materials and Processes, SSP 30233

2.1.15 Space Station cable/wire Design and Control Requirements for Electromagnetic Compatibility, SSP 30242

2.1.16 Space Station Requirements for Electromagnetic Compatibility, SSP 30243

2.1.17 Space Station Electrical Bonding Requirements, SSP 30245

2.1.18 Natural Environment Definition for Design, SSP 30245

2.1.19 Space Station External Contamination Requirements, SSP 30426

2.1.20 Safety Policy and Requirements using the ISS, SSP 30599

2.1.21 ISS Pressurized Volume Hardware Common Interface Requirements Document SSP 50835

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2.1.22 Ethernet Requirements for Interoperability with the Joint Station LAN (JSL)
SSP 50892, Baseline, June 2009

2.1.23 International Standard Payload Rack to ISS, Software ICD Part 1
SSP 52050, Rev. J, March 2012

2.1.24 Attached Payloads Interface Requirements Document
SSP 57003, Rev H

2.2 Reference Documents

2.2.1 Universal Serial Bus Class Definitions for Communications Devices
CDC120-20101103, Revision 1.2 (Errata 1), November 3, 2010
http://www.usb.org/developers/devclass_docs

2.2.2 Universal Serial Bus Communications Class Subclass Specification for PSTN Devices
CDC PSTN Subclass, Rev. 1.2, February 9, 2007;
http://www.usb.org/developers/devclass_docs

2.2.3 USB Communications Class Subclass Specification for Ethernet Control Model Devices
CDC ECM Subclass, Rev. 1.2, February 9, 2007;
http://www.usb.org/developers/devclass_docs

2.2.4 Universal Serial Bus Mass Storage Class
MSCO, Revision 1.4, February 19, 2010; http://www.usb.org/developers/devclass_docs

2.2.5 The GNU/Linux "usbnet" Driver Framework
David Brownell, last modified: 27 September 2005
http://www.linux-usb.org/usbnet/ – retrieved 02/07/2014

2.2.6 Intel HEX – http://en.wikipedia.org/wiki/Intel_HEX – retrieved 02/07/2014

2.2.7 Date and Time Format – ISO 8601
http://www.iso.org/iso/home/standards/iso8601.htm
http://en.wikipedia.org/wiki/ISO_8601 – retrieved 02/10/2014

2.2.8 File Transfer Protocol
Postel/Reynolds: Request for Comments (RFC) 959, Oct. 1985
http://tools.ietf.org/html/rfc959

2.2.9 Network Time Protocol
ntp.org: Home of the Network Time Protocol; http://www.ntp.org

2.2.10 NanoRacks External Platform (NREP) User Manual
ANA–EPP–UM–0001, Issue 1/–, <TBD>

2.2.11 NREP Command and Data Handling
ANA–EPP–TN–0001, Issue 1/C, 02/03/2015

2.2.12 Software Toolkit for Ethernet Lab-Like Architecture (STELLA) User's Guide,
D495–90807–1, Rev. A, 11/25/2013

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2.3 Documentation Hierarchy

The primary payload integration documentation consists of this SIDD and the payload ICA. NanoRacks/Airbus DS Space Systems and the payload representative will jointly approve the ICA. The relationship between the ICA, the SIDD, and other NanoRacks/ANA program documentation is presented in Figure 2-1.

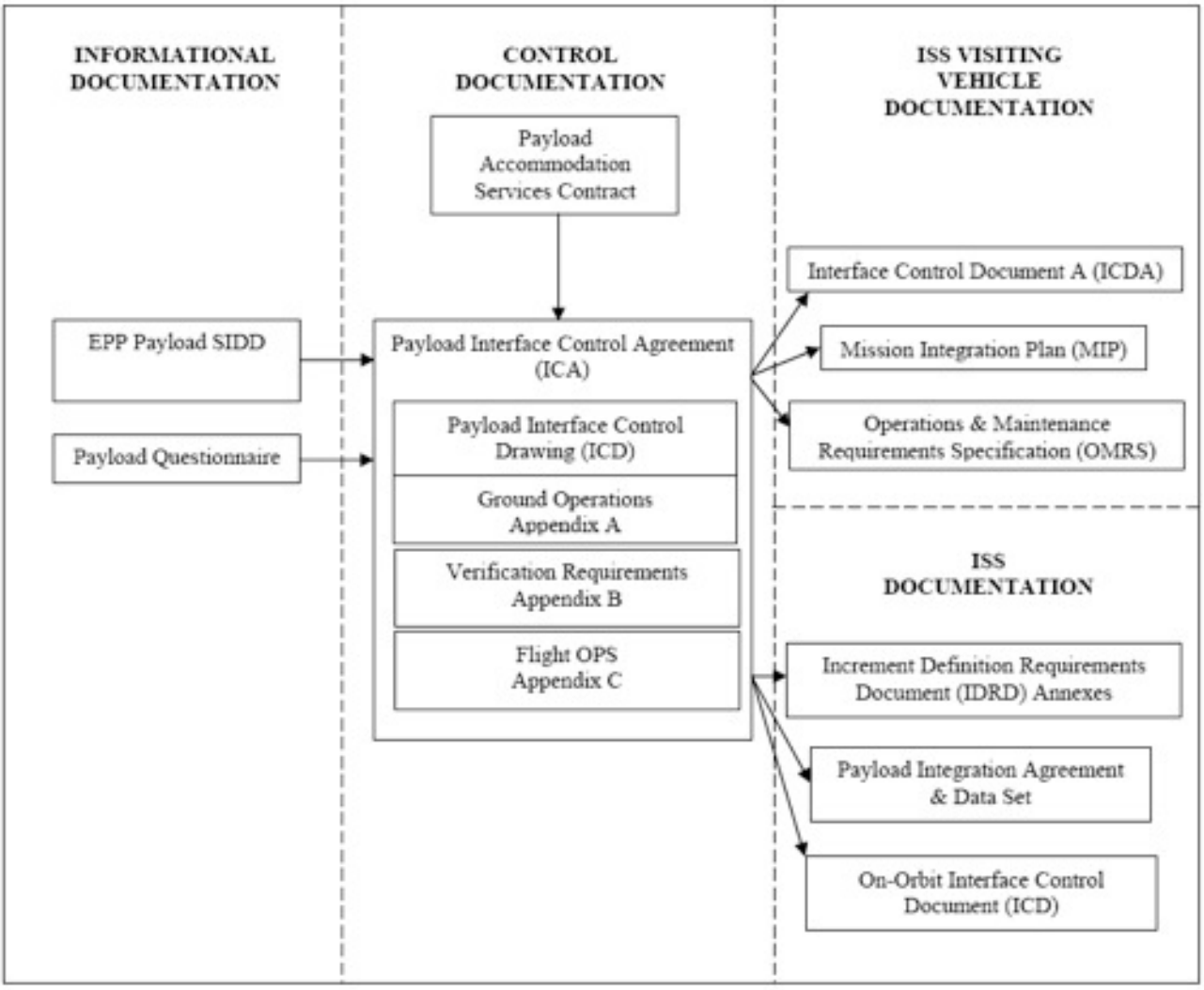
INFORMATIONAL DOCUMENTATION
CONTROL DOCUMENTATION
ISS VISITING VEHICLE DOCUMENTATION
Payload Accommodation Services Contract
EPP Payload SIDD
Payload Questionnaire
Payload Interface Control Agreement (ICA)
Payload Interface Control Drawing (ICD)
Ground Operations Appendix A
Verification Requirements Appendix B
Flight OPS Appendix C
Interface Control Document A (ICDA)
Mission Integration Plan (MIP)
Operations & Maintenance Requirements Specification (OMRS)
ISS DOCUMENTATION
Increment Definition Requirements Document (IDRD) Annexes
Payload Integration Agreement & Data Set
On-Orbit Interface Control Document (ICD)

Figure 2-1: NanoRacks/Airbus DS Space Systems Documentation Hierarchy

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3 Physical Characteristics

3.1 General

3.1.1 NREP Coordinate System

The coordinate system of the NREP is a right-handed system shown in Figure 3-1. Its origin is the center of the mating surface of PIU to the NREP, the X-axis is normal to the mating surface, and the Z-axis points to the Nadir direction.

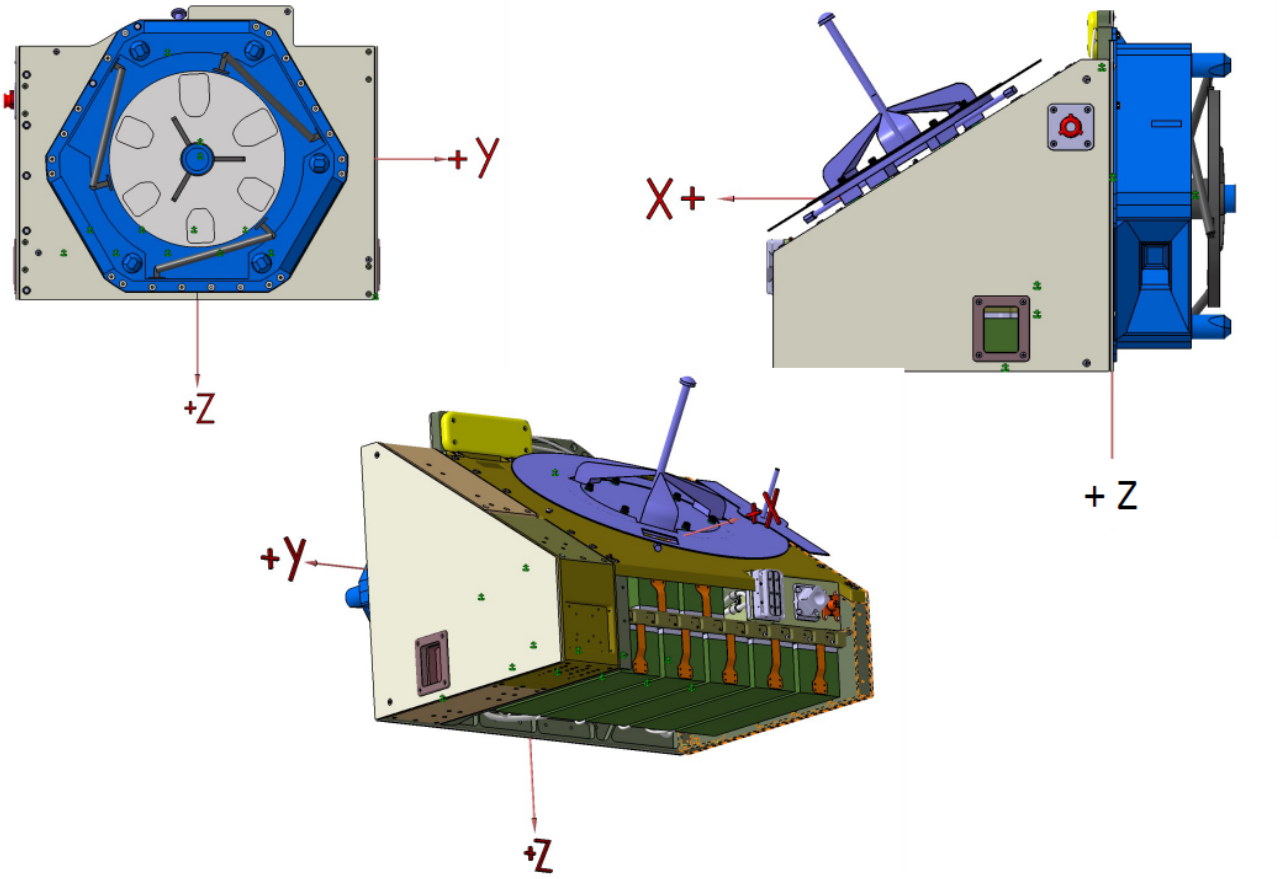

Figure 3-1: NREP External interfaces

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3.1.2 NREP General Dimensions

General dimensions of the NREP are shown in 3-2.

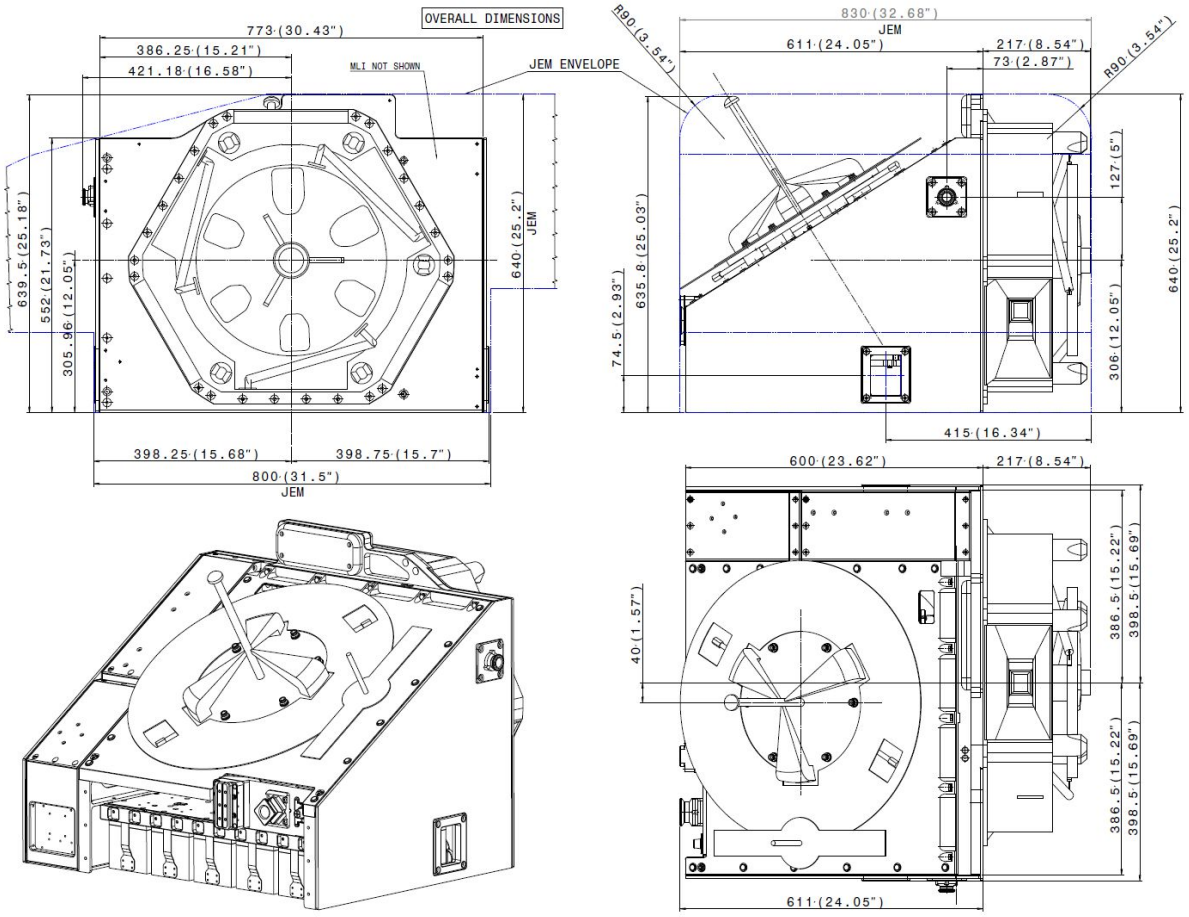

Figure 3-2: NREP Envelope Dimensions

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DIMENSIONS AND TOLERANCES

In this document, source engineering is referenced in native units (English or SI) in order to avoid tolerance errors, which may result from conversion from one standard unit of measure to another. Each Figure is annotated to identify the units used. Wherever SI units are used specific tolerances will be stated. If English units are used and no tolerances are specified, use the following.

English tolerances:

Decimal:	X.X	=	± 0.1 in.
	X.XX	=	± 0.03 in.
	X.XXX	=	± 0.010 in.
Fractions:		=	± 1/16 in.
Angles:		=	± 1°

Any deviation to the tolerances specified herein will be documented in the ICA.

3.1.3 General NREP Performance Characteristics

The NREP program supports launch to low earth orbit, transfer of payloads between ISS visiting vehicles and ISS, on-orbit operations, and return of payloads to Earth. NREP requirements are derived from SSP 50835 throughout all flight and ground support phases.

3.1.4 NREP - Payload Configurations

NREP payloads can be attached in various configurations to the NREP Baseplate. The baseplate can accommodate up to 5 powered 4U payloads and up to 4 unpowered 3U payloads or unique geometry agreed to per interface control agreement.

3.1.5 NREP - ISS Visiting Vehicle Configurations

All NREP payloads will be transported on ISS visiting vehicles in standard soft stowage hardware unless otherwise negotiated.

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3.1.6 NREP Baseplate Location Numbering System

The NREP location numbering system is shown in Figure 3-3 and also indicated by labels on the Experiment Base Plate. For payloads shorter than 4U the sites are subdivided by letters A through D (see Figure 3-4 and Figure 3-5)

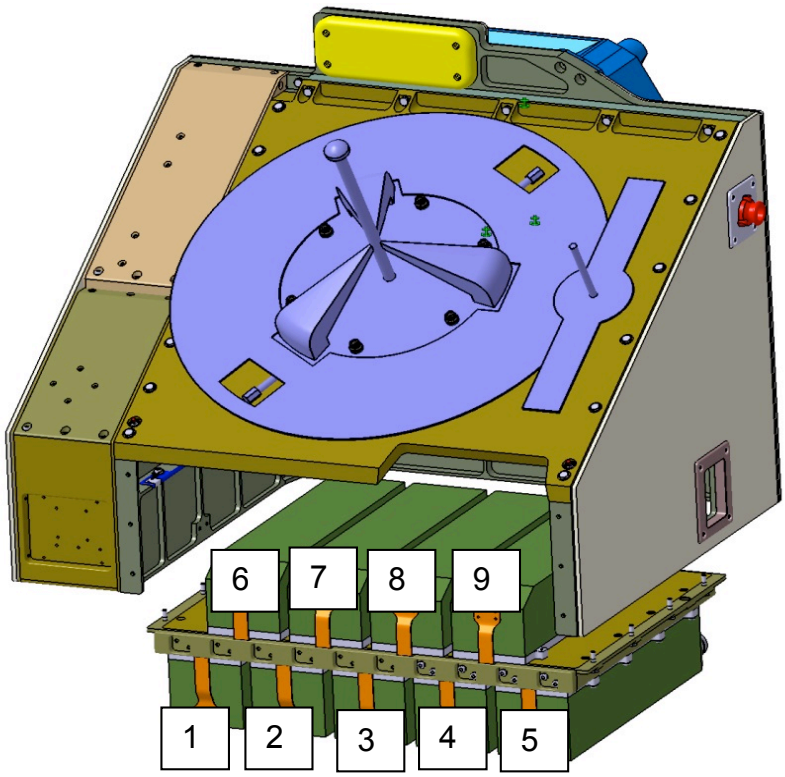

Figure 3-3: Payload Numbering System

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3.1.7 Payload Envelope for Standard and Small Non-Standard Payloads

The NREP allows for various configurations with different standard sizes of payloads. An example is shown in Figure 3-4. Standard Payloads have a width and a height of 100 mm and a length from 1U (=100mm) up to 4 U (=400mm). Due to geometric constraints payloads attached to the top side have a slightly reduced volume as indicated in Figure 3-11 and Figure 3-12.

Payloads with non-standard sizes may either use the available attachment interfaces and volume on the Experiment Base Plate (as described in Figure 3-5 through Figure 3-7) or, in case of large payloads they may use the entire available volume (see Figure 3-15).

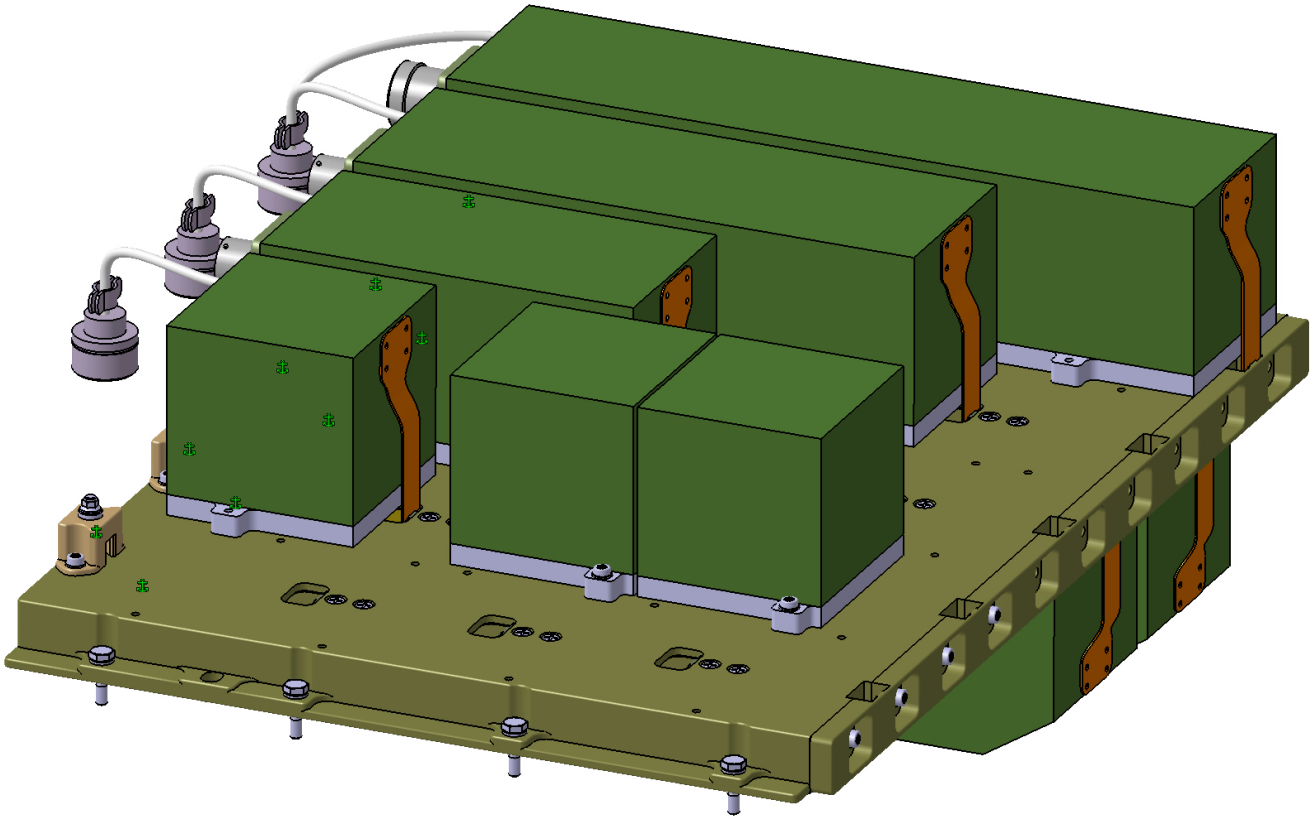

Figure 3-4: Payload Configuration Example (view from bottom)

The Figure 3-5 shows the interface for payload attachment on top of the Experiment Base Plate. The shaded areas on the left hand side indicate the foot prints of 4U standard experiments. The shaded area on the right hand side shows the maximum payload footprint limit for a non-standard payload. The left hand side payload footprint limit for non-standard payloads is identical to the left side of the 4U payload footprint.

The Figure 3-7 shows the interface for payload attachment on the bottom of the Experiment Base Plate and the location of the payload interface connectors. The available footprint for non-standard payloads is from the left side of the left hand payload to right side of the right hand payload.

The Figure 3-7 shows the maximum payload height on the experiment base plate and the location of the payload connectors.

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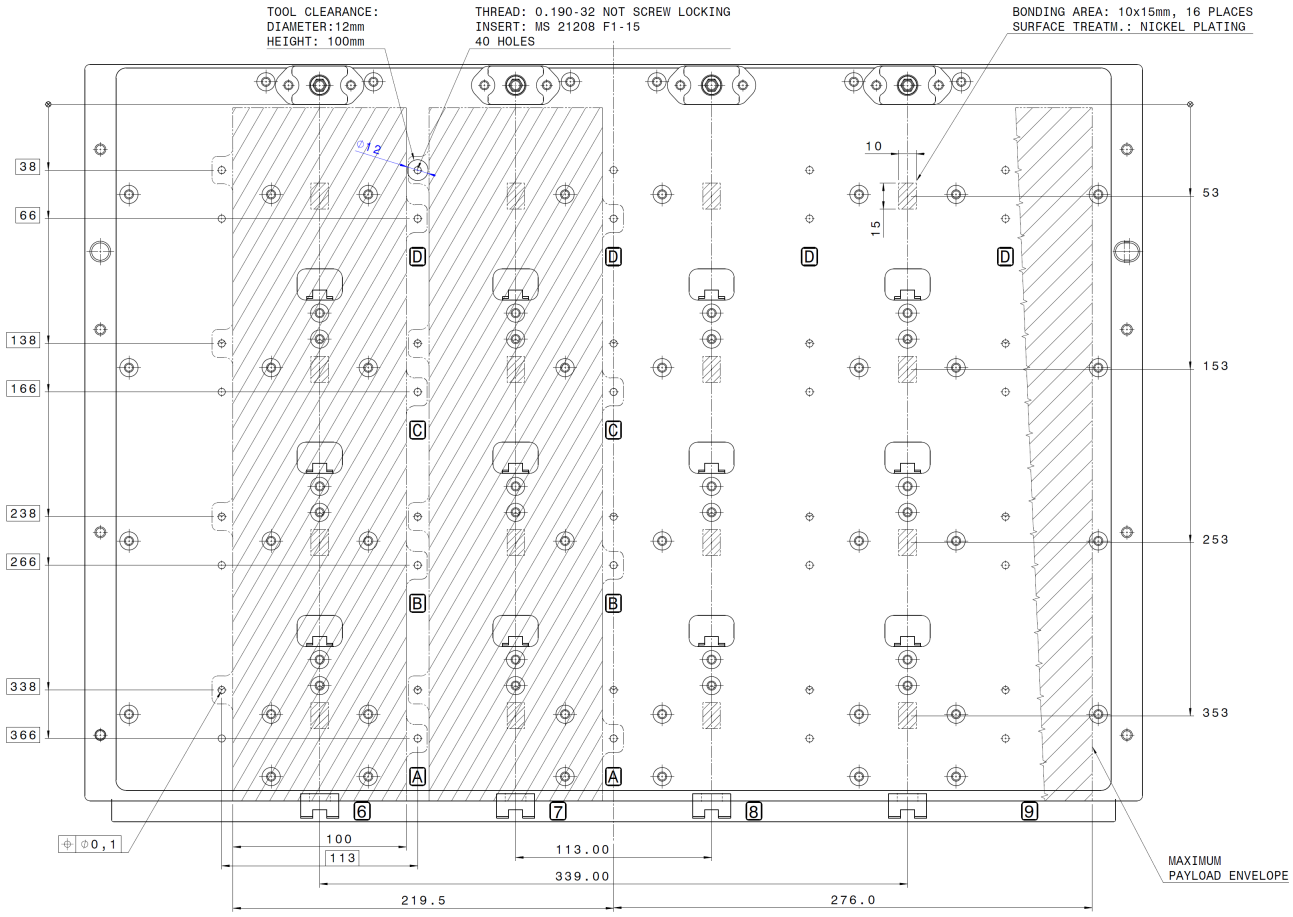

Figure 3-5: Experiment Baseplate Interfaces on Top Side

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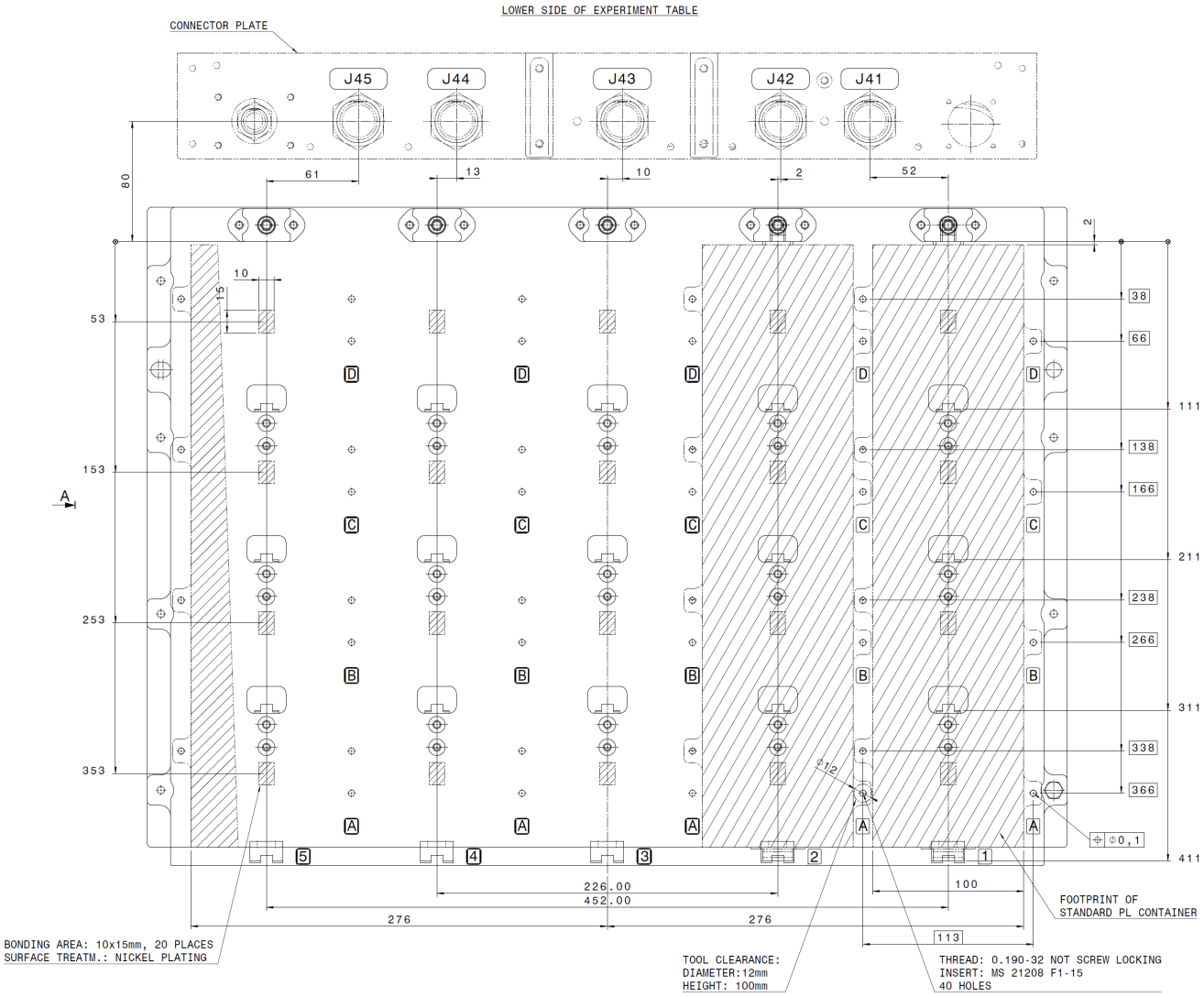

Figure 3-6: Experiment Baseplate Interfaces on Bottom Side

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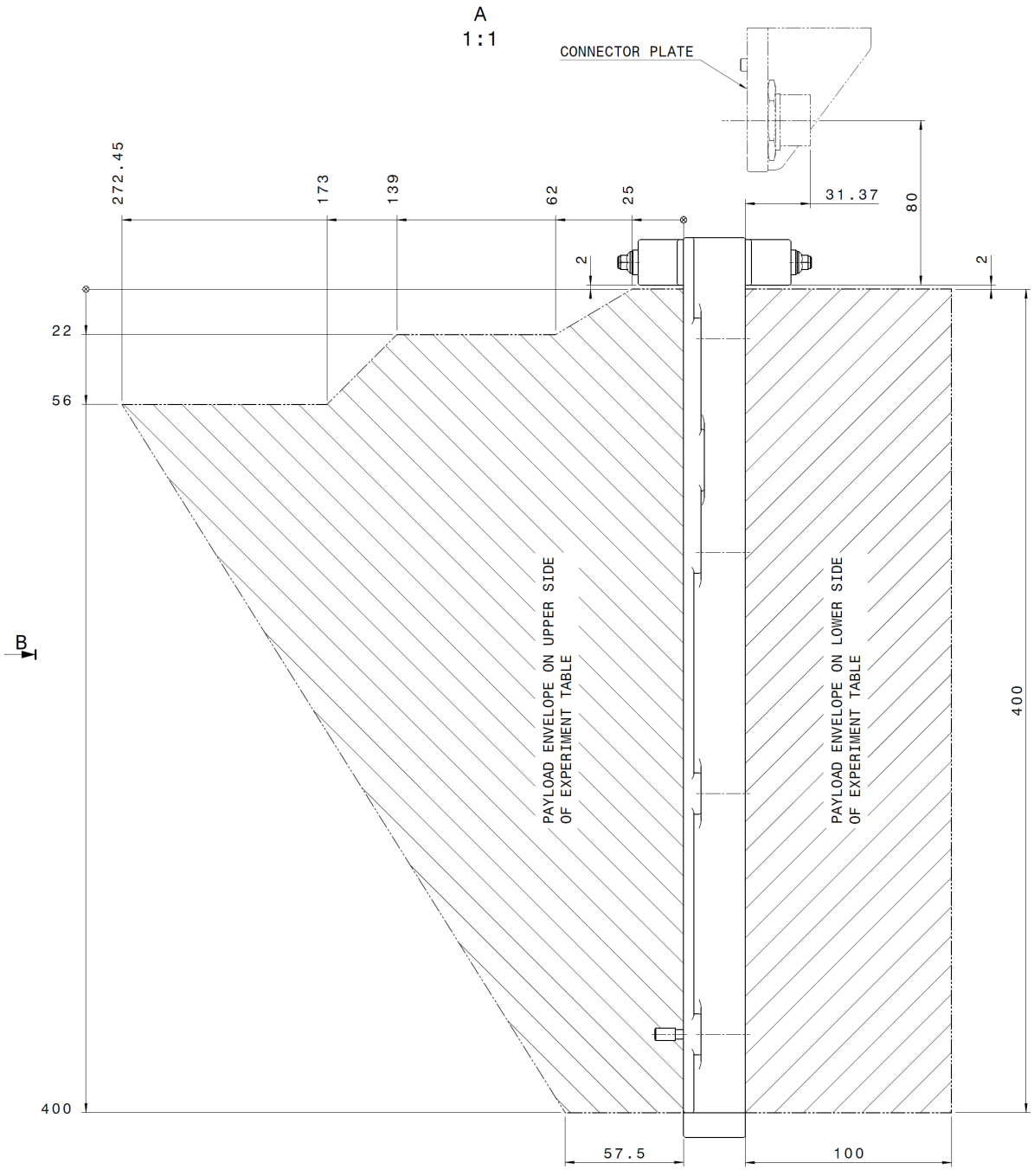

Figure 3-7: Payload Envelope Side View

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3.1.8 NREP-P Dimensions for Standard Payloads

The dimensions for the NREP standard payloads are shown in Figure 3-8 through Figure 3-12.

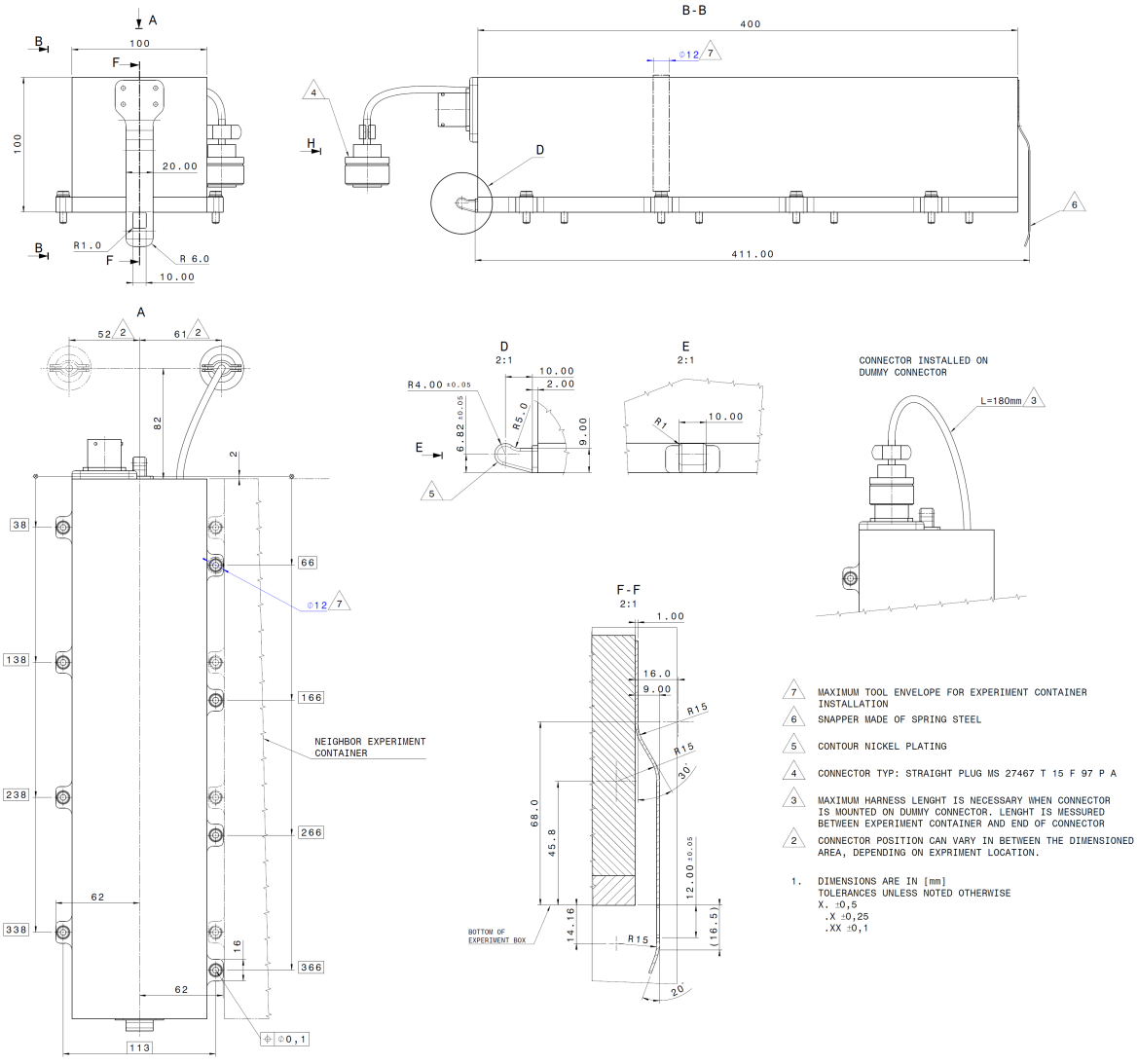

Figure 3-8: Bottom mounted 4U Standard Payload including standard soft-dock feature

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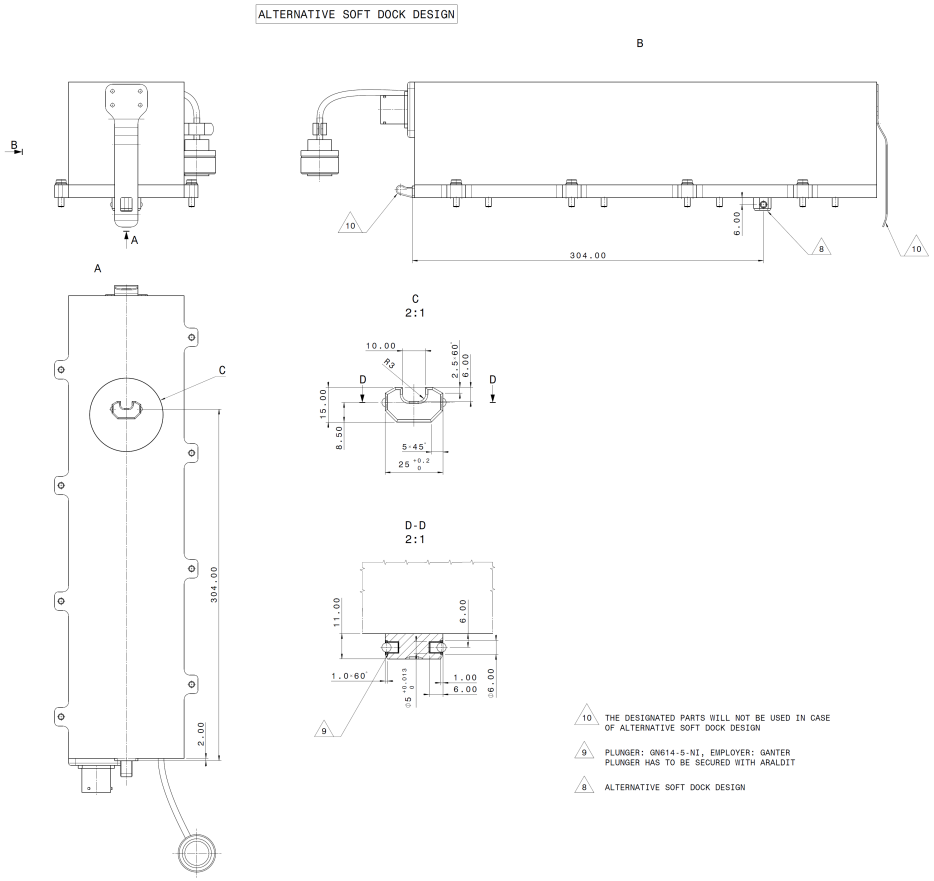

Figure 3-9: Bottom mounted 4U Standard Payload including alternative soft-dock feature

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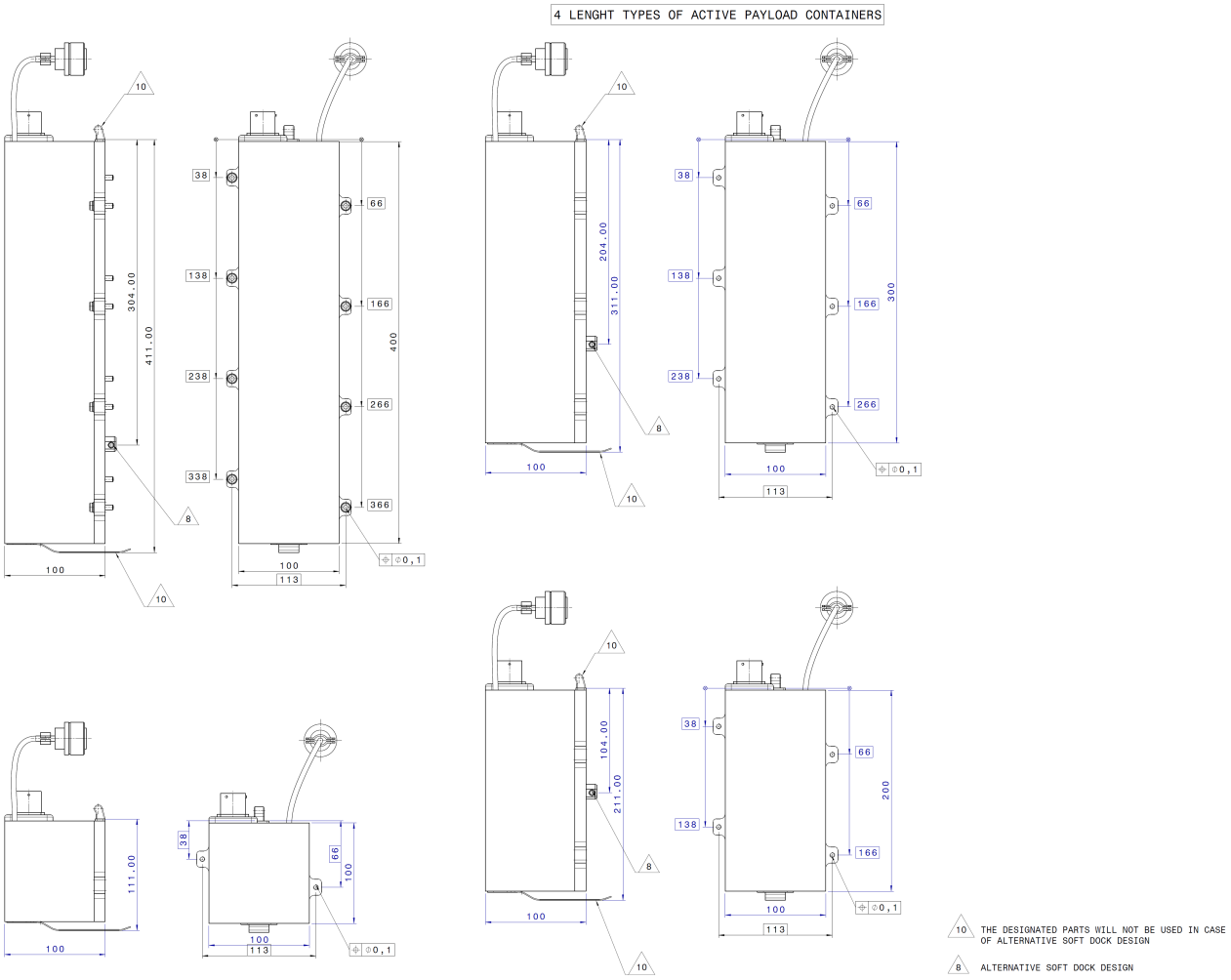
4 LENGHT TYPES OF ACTIVE PAYLOAD CONTAINERS
10 THE DESIGNATED PARTS WILL NOT BE USED IN CASE OF ALTERNATIVE SOFT DOCK DESIGN
8 ALTERNATIVE SOFT DOCK DESIGN

Figure 3-10: Dimensions for different bottom mounted payload sizes

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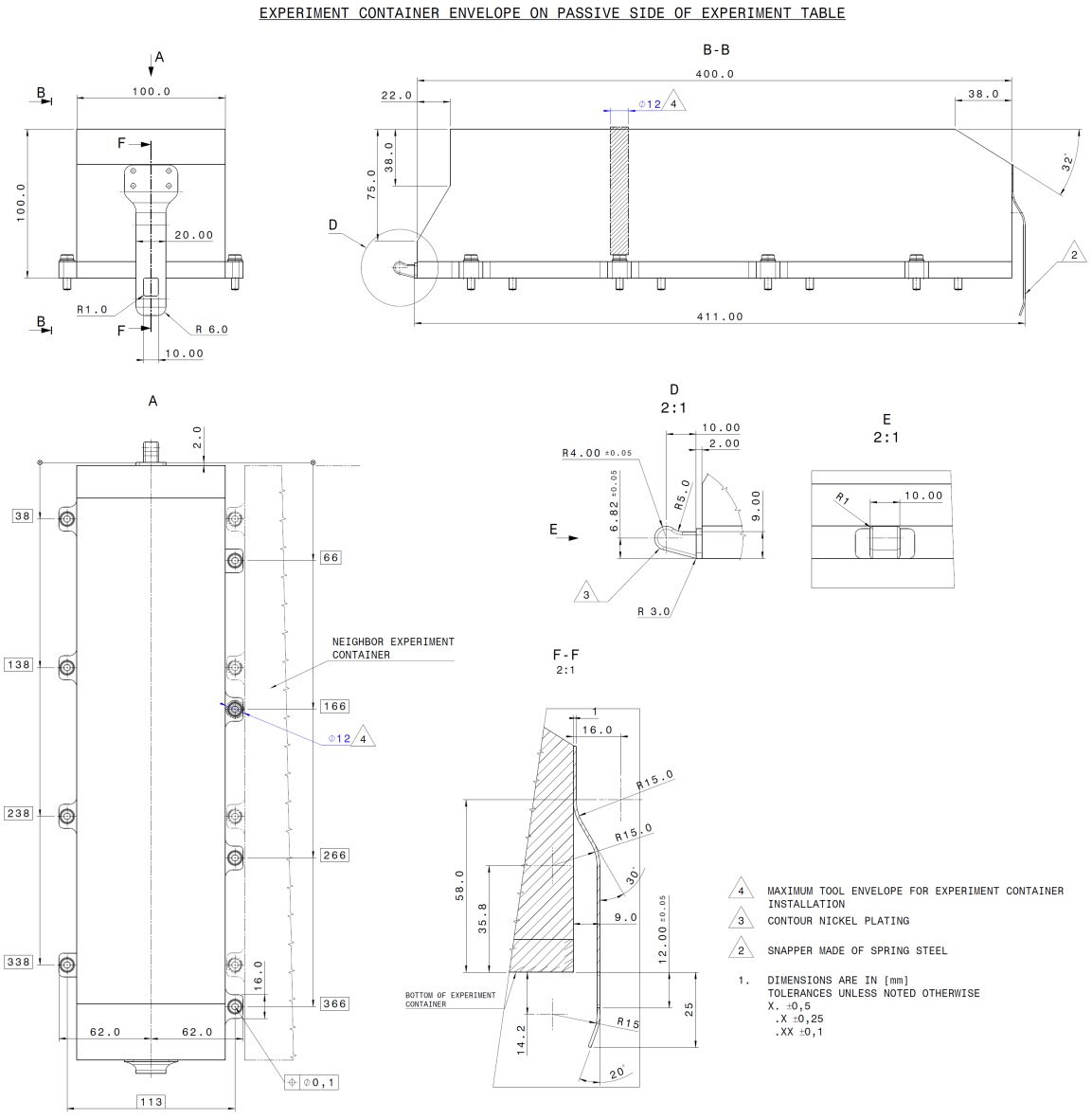

Figure 3-11: Top mounted 4U Standard Payload including standard soft-dock feature

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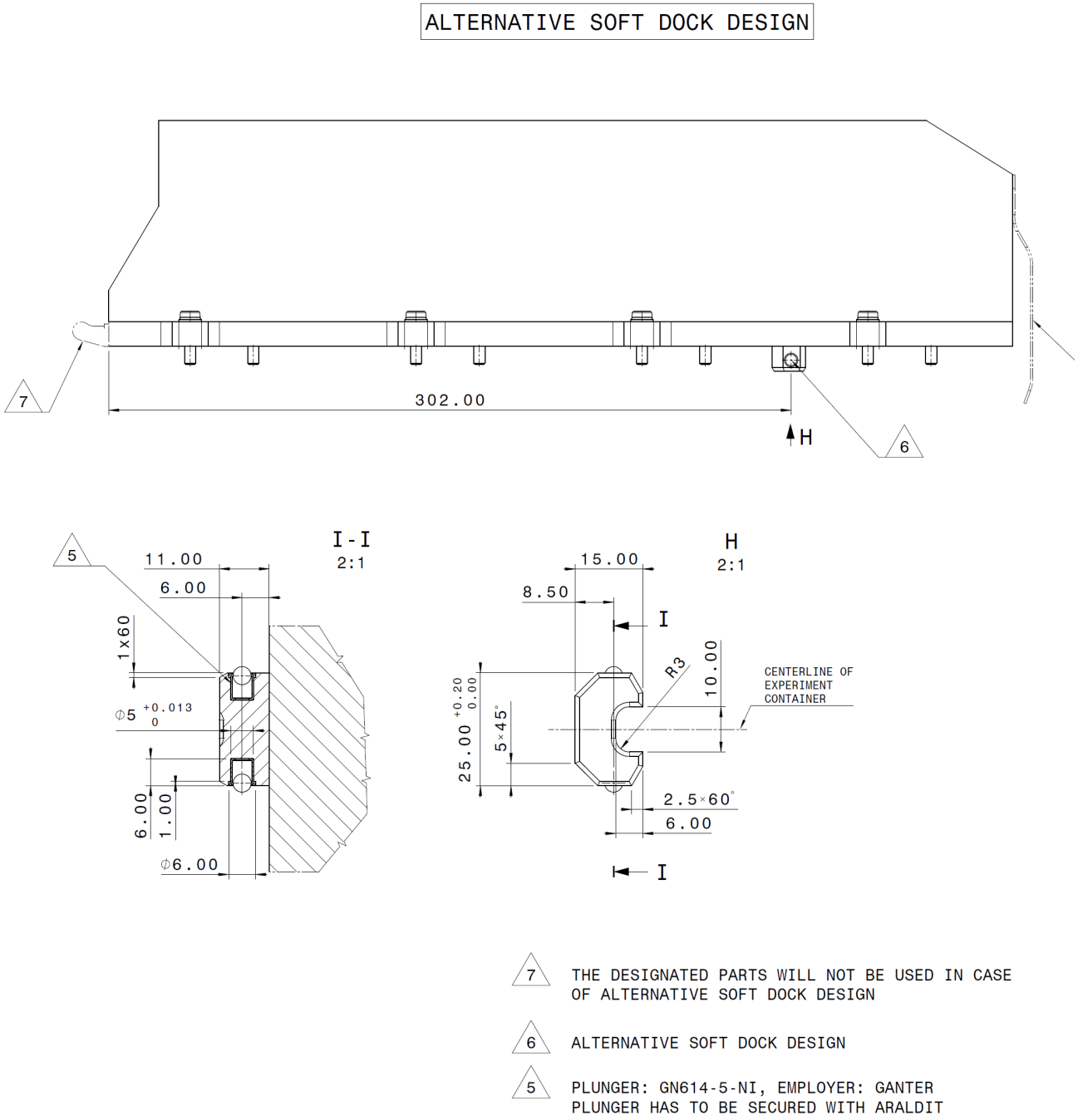

Figure 3-12: Top mounted 4U Standard Payload including alternative soft-dock feature

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3.1.9 NREP-P Attachment to Experiment Baseplate

The payloads shall provide a soft dock feature as described in the figures above. All fasteners shall be captive and of hex socket (Allen) type. For positive fastener locking the bolts shall be equipped with locking features (e.g. according to NAS1283 type P). Two fastener locations are provided per 100mm payload length. A payload provider with a 2 U or larger payload might opt to not use all available positions; however a minimum of 2 fasteners is required.

3.1.10 NREP-P Bonding to Experiment Baseplate

The payloads shall provide for structural bonding to the designated bonding areas on the Experiment Baseplate as identified on Figure 3-5 and Figure 3-6. An example of a bonding tab is shown in Figure 3-13.

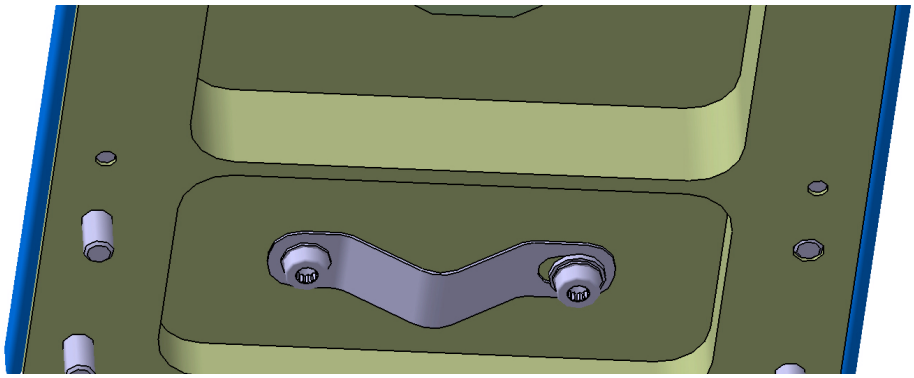

Figure 3-13: Example of a Bonding Tab

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3.1.11 Payload Envelope for Large Non-standard Payloads

Large Payloads can be accommodated if they installed instead of the Experiment Baseplate and are directly attached to the NREP Main structure. The available volume is shown in Figure 3-14.

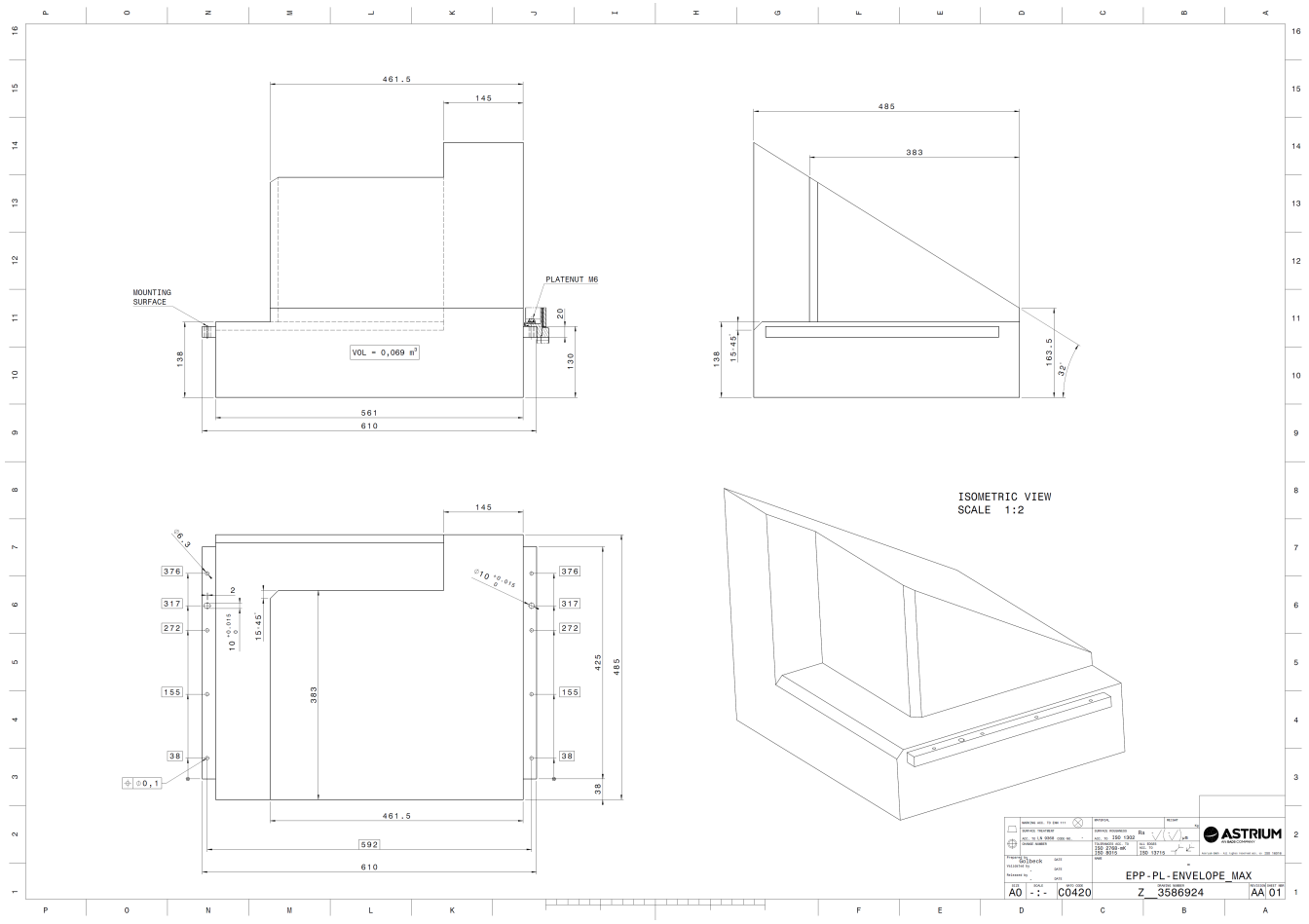

Figure 3-14: Payload Envelope for large Non-Standard Payload

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3.1.12 Attachment of Large Non-Standard Payload to NREP Structure

The large payloads shall provide for soft dock feature and bolted attachment identical to the Experiment Baseplate. Soft-dock is achieved through holes that interface to pins with spring loaded balls as shown above. The fasteners shall be captive and have an M6 thread. The bolts interface with self-locking nut-plates so the bolts do not need own locking feature.

3.1.13 Bonding of Large Non-Standard Payload to NREP Structure

The payload shall provide for nickel-plated surface at the interface to the NREP structure for faying surface bonding.

3.1.14 NREP Payload Mass Capacity

The maximum gross NREP payloads mass capacity is as follows:

- For NREP-P 4U (Standard Payload) : 4kg nominal mass unless otherwise negotiated
- For NREP-P Base-plate Capable Mass (Unique Payload): 35kg

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4 NREP Structural Interfaces

The NREP payloads have to withstand the launch environment in their individual stowage configuration. Loads are largely dependent on the selected stowage material (bubble wrap, foam material) and configuration (cargo transfer bag, CTB) inside rack or mounted to rack front. The launch environment for different configurations is specified in SSP50835.

On orbit the payloads have to withstand the on-orbit accelerations of 0.2 g simultaneously in any direction.

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5 Thermal Interfaces

5.1 General

5.1.1 Material Properties

Description	Density [kg/m³]	Material	T [K]	λ [W/(m*K)]	c_p [J/(kg*K)]	Solar Absorptivity	Infrared Emissivity
BASEPLATE Structure	2700	Aluminum 7075, white painted (SG120D)	50	43.7	148.4	0.2	0.87
			150	89.7	673.1		
			250	116.7	848.0		
			273	120.6	869.2		
			400	136.5	906.3		

Table 5-1: Thermo-optical and Thermo-physical Properties

Payloads shall deliver BOL thermo-optical properties due to the fact that their missions are short term only.

5.1.2 NREP Payloads Attached to the ISS

The worst-case thermal environments for an ISS attached NREP will be considered on a case-by-case basis due to the complexity of the ISS thermal environment.

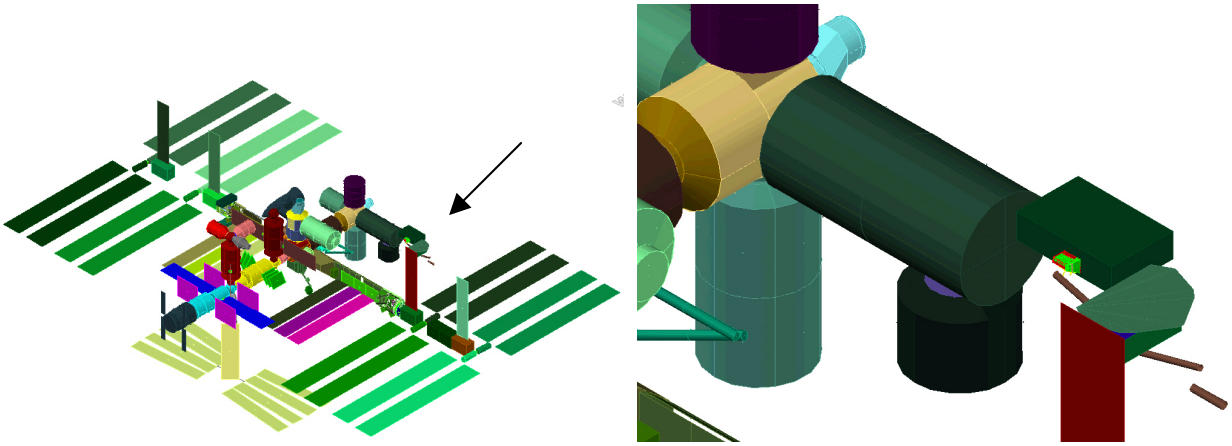

Figure 5-1: NREP Location

Airbus DS Space Systems will perform analyses for the mission specific worst hot and worst cold case and one or two intermediate angles for the ISS attitudes during the mission.

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6 Electrical Interfaces

6.1 General

Electrical services are available via 5 NREP payload interface connectors. The connectors are located at the rear side of the base-plate. The interface to the payload provides a switchable 28 VDC power outlet with a maximum power of 50 W @ 28 VDC. Additionally a 5 VDC power supply is provided with the USB 2.0 data bus. The maximum current is 500 mA. The 5 V power is non switchable and available while the DHS is powered. Details about the maximum available 28 VDC power is defined and documented in the NREP payload-specific ICA.

Where required, additional NREP non-standard services, such as 120 VDC power interface, can be provided and are defined and documented in the NREP payload-specific ICA.

6.2 Electrical Provisions - 28 VDC

6.2.1 Constraints - 28 VDC

The NREP provides bracket-mounted connectors for up to 5 payloads. Each connector provides 28 VDC power and a USB 2.0 data interface including a separate non-switchable 5 V/500 mA bus power.

The 28 Vdc NREP electrical receptacle interface is defined in Table 6-1.

The specification of the interface connector is provided in

Table 6-2.

Table 6-1: Receptacle Interface Definition - 28 VDC & USB

Designation: J41.. J45

Signals: NREP-P Power & USB Lines

Location: NREP

Pin No.	Signal Name	Size	Type	Class	Voltage Level	Max. Current
C	Power +	16			28 VDC	2 A
M	Return	16			0	
G	Ground	16			0	
L	nc	16				
A	USB data +	20				
B	USB data -	20				
K	USB PWR +	20			5 VDC	500 mA
J	USB PWR -	20			0	

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Table 6-2: Connector specification

Designation	Description	Nomenclature	Quantity	Size
J41..J45	Jam Nut Receptacle	MS 27468 T 15 F 97 S A	5	15
P1	Straight Plug	MS 27468 T 15 F 97 P A	5	15
-	Contacts		4	AWG 16
-	Socket		4	AWG 16
	Contacts		8	AWG 20
	Socket		8	AWG 20
	Back Shell	MS 27506 F 14 2	5	

Each payload that requires power and data interfaces has to provide a harness pigtail with the specified connector. The length of the cable shall be in the range of xxx to yyy inch. The wire size inside NREP-P shall be at least 20 AWG up to an internal fuse. Each NREP payload shall provide a dummy connector to hold the connector cap of the NREP power outlet while the NREP payload is attached to the NREP.

6.2.2 28 VDC Power Characteristics

In the following the standard 28 VDC power outlet characteristics are defined:

Voltage range: 28 V +/- 2 V

Transient over-voltage: 40 V

Nominal power: 30 W at 28 V

Maximum current: 2 A

Over-current protection: 4.8 A, trip time 2 ms

6.2.3 5 VDC USB Power

The 5 VDC USB power is specified according to the USB 2.0 High Power standard, allowing a maximum current draw of 500 mA. The power is permanently applied on the NREP side; however, in order to be able to control all power draw by a payload, the payload is required to inhibit any 5 VDC USB power draw while the 28 VDC power is not applied.

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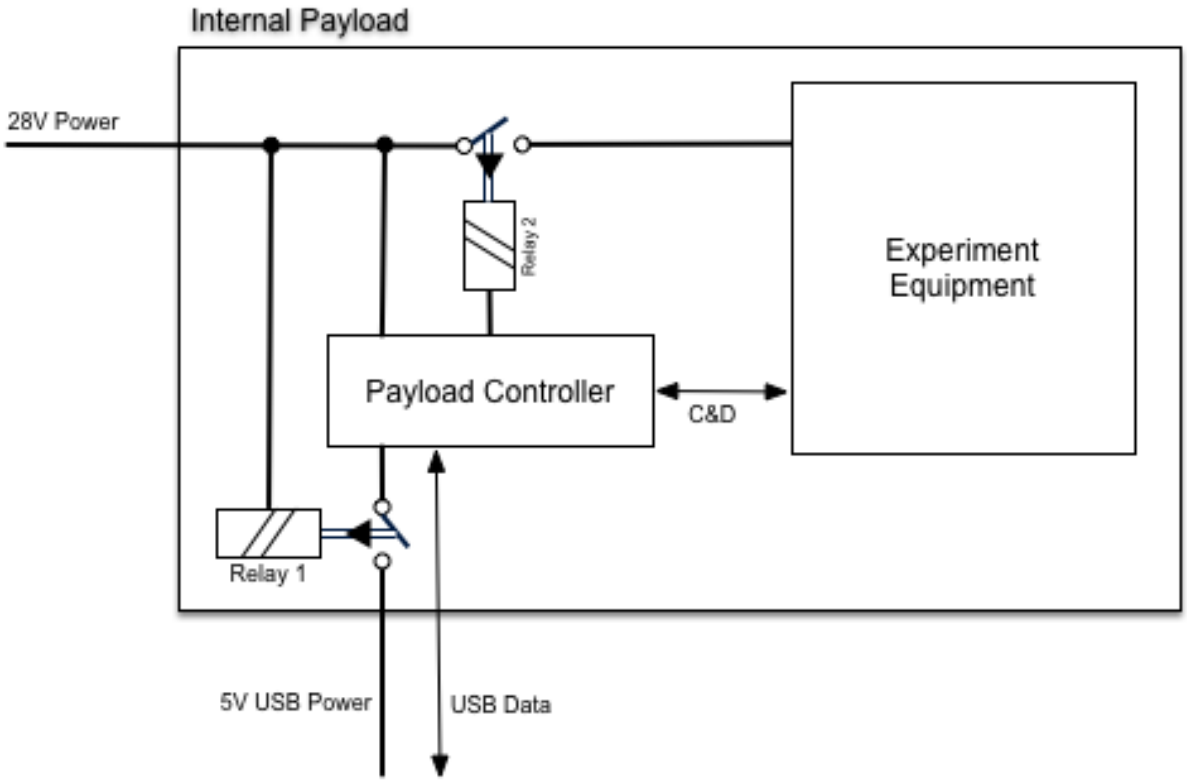

Figure 6-1: Payload Power Control

Figure 6-1 shows a possible implementation of payload power control. The two shown relays inside the payload, Relay 1 and Relay 2, both default to an "off" position. Relay 1 is activated by the external 28 VDC power, and connects the 5 VDC USB power. Relay 2, an optional means to control power to the actual experiment, is controlled by software (default "off", may be commanded to "on" or back to "off").

A payload that uses only the 5 VDC/500 mA USB power nevertheless needs to switch that power draw based on the presence or absence of the 28 VDC power. Conversely, a payload that does not use USB power at all does not have to take measures to disconnect it.

Analogous to the USB power control requirement, an internal payload is also required not to show USB data activity while the 28 VDC power is off.

6.2.4 Electrical Provisions - 120 VDC

120 VDC electrical power is a non-standard service and shall be defined and documented in the payload-specific ICA.

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7 Electromagnetic Compatibility

7.1 Electrical Grounding

The NREP-P electrical grounding shall be in accordance with SSP 30240, paragraph 3.2.

7.2 Electrical Bonding of Equipment

The NREP-P shall be electrically bonded to the NREP base plate per SSP 30245, *Space Station Electrical Bonding Requirements,* paragraphs 3.2 and 3.3.

7.3 Payload Surface Electrostatic Charging

All NREP-P metallic hardware elements shall comply with the Class-S bond requirements of SSP 30245, *Space Station Electrical Bonding Requirements*.

7.4 Insulated Materials

Hardware consisting of or containing low-conductivity material shall be bonded in accordance with SSP 30245, Section 3.3.4.3.2.

7.5 Radiation Emissions

The NREP-P shall not exceed emissions defined in SSP 30237, Space Station Electromagnetic Emission and Susceptibility Requirements

.

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8 Materials Compatibility and Safety

8.1 Materials and Processes

Materials and processes used in the design and fabrication of payloads and associated support equipment shall comply with NSTS 1700.7B, *Safety Policy And Requirements For Payloads Using The International Space Station*. The payload representative will submit a Material Identification Usage List (MIUL) to the NREP service provider. The MIUL will identify all materials used in the payload, material usage, and flammability ratings for each material. Toxicity ratings for each material, not offgas tested, shall also be included. Determination of flammability and offgas ratings shall be in accordance with NASA-STD-6001, *Flammability, Odor, Offgassing, And Compatibility Requirements And Test Procedures For Materials In Environments That Support Combustion*, and MSFC-HDBK-527, *Materials Selection List for Space Hardware Systems*.

8.2 Safety Process

In the process for safety approval by ISS authorities the NREP service provider will analyze the MIUL to identify safety hazards and payload produced emissions in order to mitigate them to a level acceptable by ISS program.

8.3 Toxic Materials

Any payload containing hazardous materials shall notify the NREP service provider prior to L-6 months for approval and inclusion in the Hazardous Materials Summary Table. The payload representative shall identify any necessary changes to the materials list latest at L-2 months.

8.4 Safe without Service

ISS / NREP provided services such as, power, or command and data, may not be available under certain conditions. In such events, the payload shall not cause a hazard to the ISS, NREP hardware, or to personnel under any conditions.

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9 Flight Operation

The launch, on-orbit installation and operation for TBD days are standard NREP-P service. The payload representative will be notified of the status of its hardware. Ten working days prior to NREP-P activation the NREP-P representative will be notified and shall ensure his support for flight operations.

During the experiment performance the user can update his experiment via file uplink. Frequency and lead-time for updates will be defined in the ICA.

During and after the experiment performance the NREP-P provider will receive its data in a format and according to a schedule as defined in the NREP-P ICA.

If parts of or the complete NREP-P need to be returned to the ground, this will be defined in the ICA.

For options regarding ground-to-payload communication, see also chapter 11.1.

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10 Payload Provider – Data Deliverables – if applicable

This section is provided for reference and details some (but not all) of the standard data to be delivered by the payload provider. **All data deliverables will be defined in the payload ICA.**

10.1 NREP-P drawings

A top-level payload drawing shall be provided showing the general dimension and the interfaces to the NREP.

10.2 Thermal Math Model Requirements

10.2.1 Payload Thermal Mathematical Model (PTMM)

A reduced mathematical model of less than 50 GMM/TMM nodes shall be delivered.
For passive payloads a boxlike model with thermo-optical properties is feasible.

The thermal model must be functional steady state and transient. The thermal model shall be ready for integration, i.e. no functions, nodes etc. have to be deactivated by the integrator.
Default names, e.g. main for submodels, htl1 for heater control, etc., shall not be used. Payload specific names shall be used in the thermal model.

Avoid a high number of registers. The number of registers is limited in SINDA and there are other experiments too.

Avoid calculations in the TMM; the TMM should contain pure numbers as far as possible.

10.2.2 Thermal Model Information Requirements

The following PTMM information shall be provided with each payload thermal analysis report:

- Nodal designation
- Allowable maximum and minimum temperatures for operating, non-operating, or safety cases, and the node numbers to which the limits should be applied
- Nodes/surfaces involved in EVA activities
- Solar absorptivity, both BOL (due to short term mission)
- Infrared emissivity, both BOL (due to short term mission)
- Internal power dissipation timeline (if there is any)

All model data shall be provided in English Units, see Figure 10-1.

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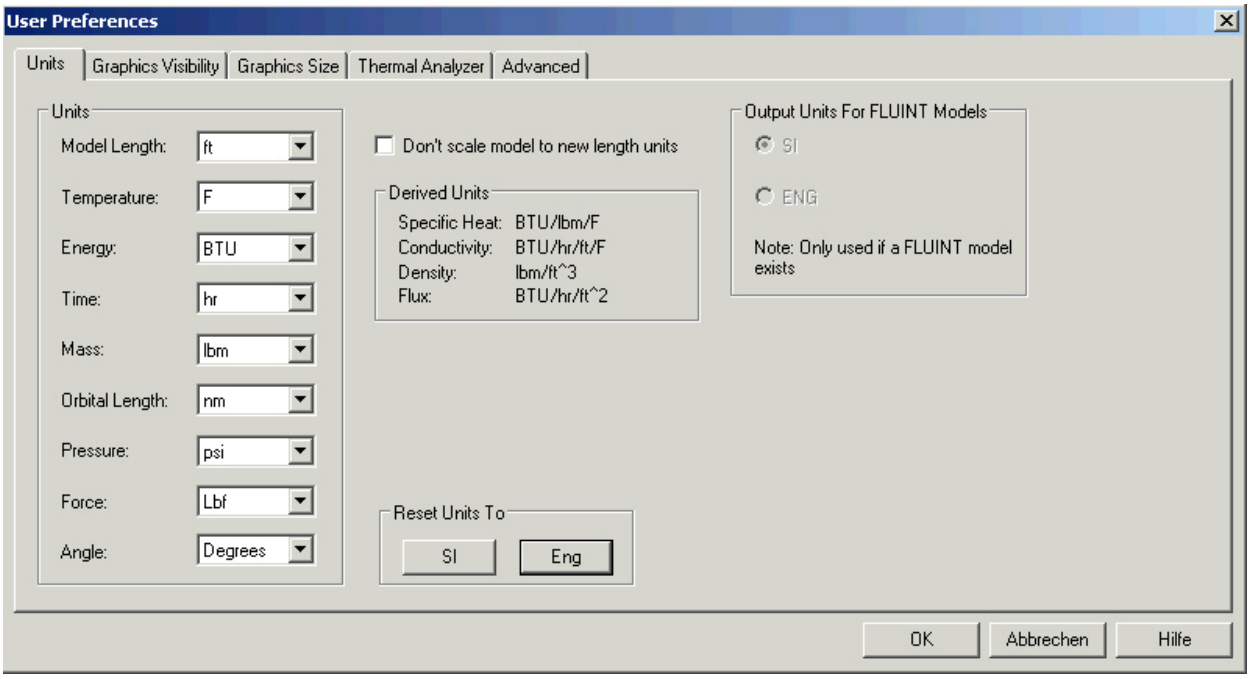

Figure 10-1: Thermal Model Engineering Units

10.2.3 PTMM Software Format

In addition to the model hard copy data tables, the payload geometric and thermal models shall be delivered on DOS compatible storage format. TRASYS or THERMAL DESKTOP format shall be used for the geometric models and SINDA/FLUINT format is required for the thermal models. All models shall be well documented within the model files. A correlated reduced PTMM shall be included and provided to EADS-ANA.

Remark:

An integrated Thermal Desktop thermal model is preferred - but the model must be TRASYS/SINDA compatible.

If you are using for thermal model setup e.g. Thermal Desktop please perform a TRASYS export and check the re-imported TRASYS file with Thermal Desktop and the original SINDA file.

Note: TRASYS does not support all Thermal Desktop features.

For information:

Airbus DS Space Systems is using AutoCAD Inventor Professional Suite 2011 with Thermal Desktop; they can support you as an optional service at the setup of the thermal model.

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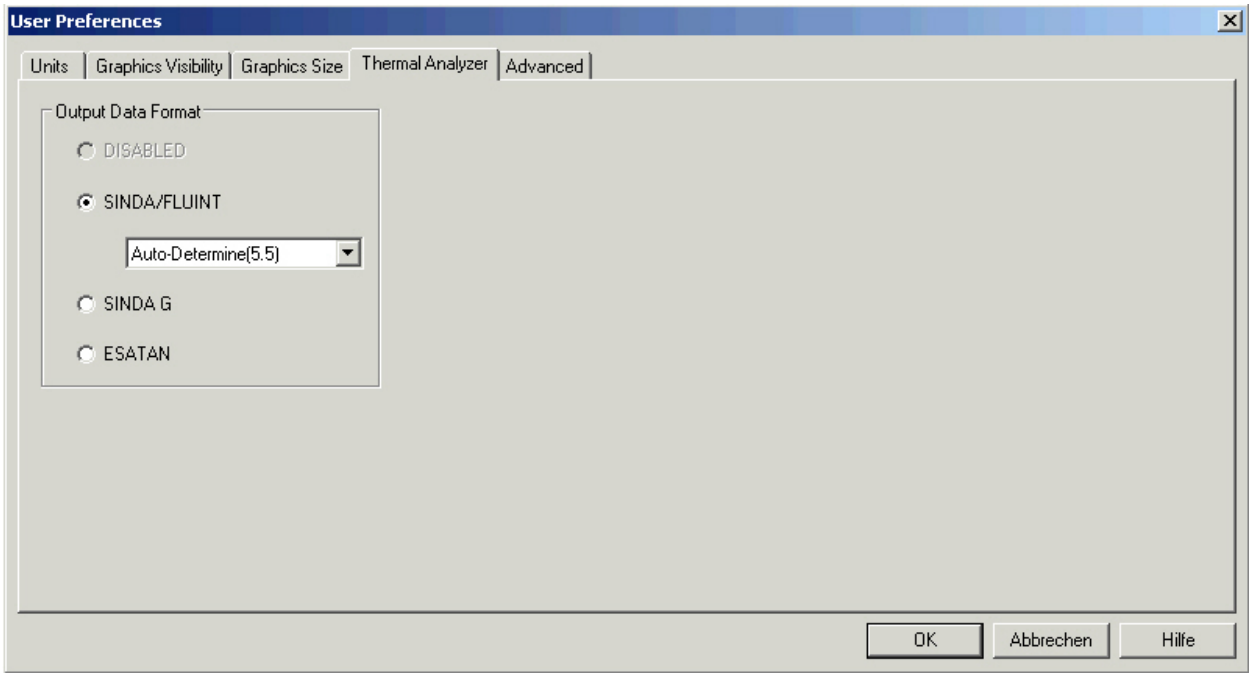

Figure 10-2: Thermal Analyzer

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11 Command and Data Interfaces

11.1 Ground to Payload Communication Overview

There are two separate command and data paths between the ground and the NREP (and hence, the NREP-P payloads), see Figure 11-1.

The standard ISS Command and Data Handling (C&DH) path is reserved for NanoRacks/Airbus DS Space Systems and NASA operators. A pseudo-network communication path via STELLA is accessible to NREP-P payload owners to send commands to their own payload and to initiate file transfers to and from their payload, using the NanoRacks platform onboard the ISS as an intermediate staging area.

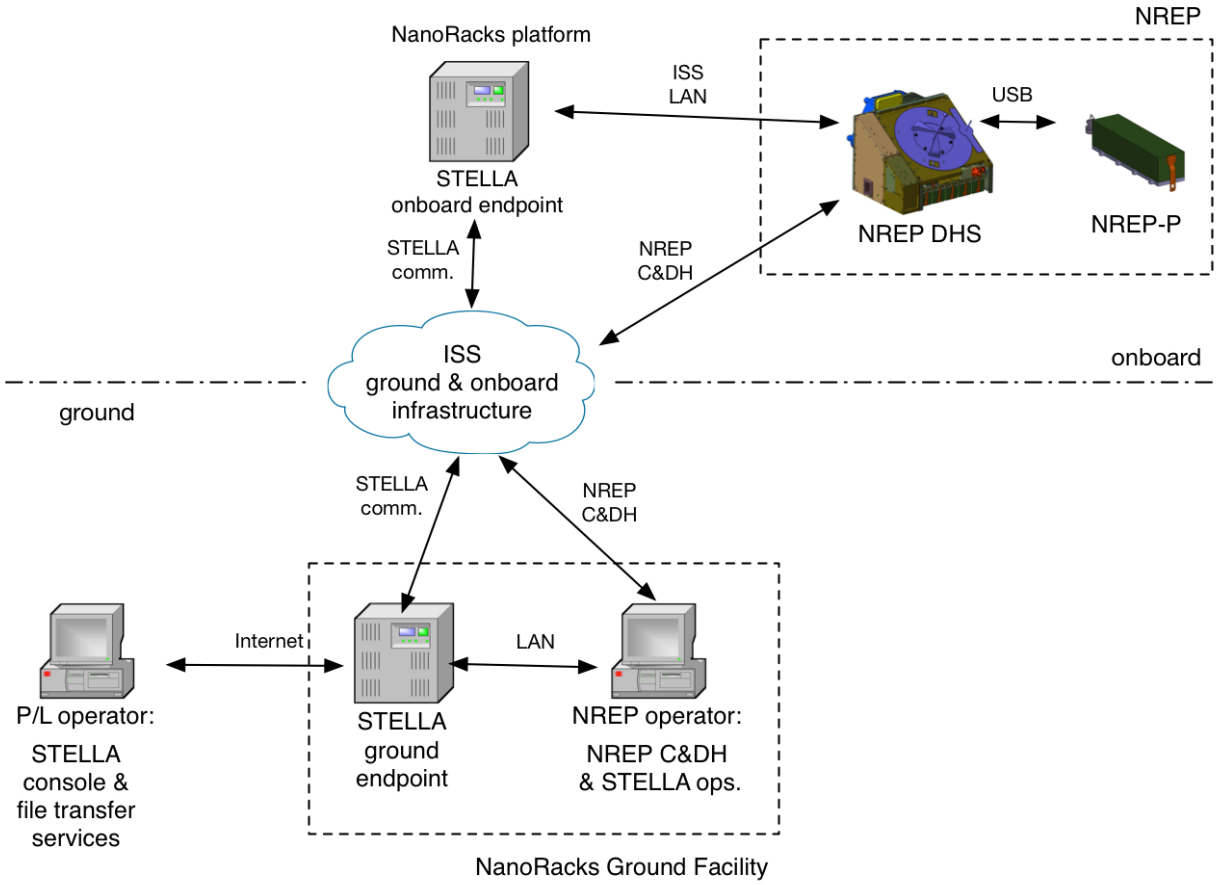

Figure 11-1: Ground to NREP-P Communication

Note: for all communications it has to be taken into account that the data links between the ISS and the ground are not continuous, but are subject to a periodic Loss of Signal (LOS) as the ISS orbits the earth, depending on relative positions of NASA's system of communications satellites. LOS periods may occur one or more times per 90-minute orbit, and may last from seconds to tens of minutes. Some communication channels (Health & Status, MRDL telemetry) are buffered on the ISS during LOS and will be transmitted once the communication link is re-established.

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11.1.1 Standard ISS Command and Data Handling

11.1.1.1 Overview

This communication path, based on the traditional space station command and data handling protocols for ISS payloads (AD 2.1.23), is used by the operators at the NanoRacks ground facility, as well as at NASA's Payload Operations and Integration Center (POIC) in Huntsville, to control and configure the NREP DHS itself, including all internal payloads and shared resources, such as data streaming destinations.

This interface is formalized in AD 2.1.2, and described in detail in RD 2.2.11.

The data downlink along this path includes Health and Status monitoring data for the NREP DHS and all its payloads using the ISS's standard low-rate MIL-1553B data bus, plus additional telemetry data streams using the (faster) Medium Rate Data Link (MRDL), some of which are exclusively used by the NREP DHS itself, and some shared by the NREP-P payloads.

The NREP C&DH interface also includes file transfer capabilities directly between the ground and the NREP DHS (and from the to/from NREP-P payloads in a second step), or between the NREP DHS and the NanoRacks platform on orbit.

NREP-P payload owners do not have direct access to this command interface, but may receive data from the NanoRacks/Airbus DS Space Systems ground facility, in the form of (a) streaming Health and Status data, derived from NREP Health and Status information filtered by payload, and (b) telemetry data related to their payload, de-multiplexed from the NREP telemetry streams (see sect. 11.3.4 for more detail).

NanoRacks/Airbus DS Space Systems may provide in the future an integrated graphical user interface for payload operators, allowing them to command their own payload, and to view status information and receive streaming data originating from standard C&DH.

11.1.1.2 File Transfer

The following options for file transfers are available and covered by NREP commands:

Table 11-1: File Transfer Options

from \ to	Ground	NR Platform	NREP DHS	NREP-P payload
Ground	—	*(STELLA)*[1]	1553[3] Uplink	—
NR platform	*(STELLA)*[1]	—	FTP	FTP[2] or Serial
NREP DHS	1553[3] or MRDL[4]	FTP	—	FTP[2]
NREP-P payload	—	FTP[2]	FTP[2] or Serial	—

[1] Transfer without NREP DHS involvement; see STELLA file transfer section 11.1.2.1.8

[2] Only payloads implementing IP networking over USB (see 11.2.1.2)

[3] Requires collaboration with HOSC operators for transferring files to/from the Payload MDM on the ISS

[4] Not yet implemented in V1.0 of the NREP DHS software

Since direct file transfers between ground and NREP-P payloads are not possible, one or two intermediate steps (via NR Platform and/or NREP DHS) are required.

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11.1.1.3 Data Streaming

The NREP provides two MRDL telemetry streams that may be shared by all payloads. The NREP DHS multiplexes incoming UDP data packets from multiple payloads in such a way that the NanoRacks Ground Facility can de-multiplex them into separate data streams, addressed to payload owners. In the current NREP DHS version, incoming packets are limited to 1484 bytes.

The NREP also supports up to 5 configurable streaming destinations (by IP address/port), which can, e.g., be set up in such a way that they correspond to configured STELLA UDP service ports forwarding packets to payload owners. See Figure 11-2 for an example.

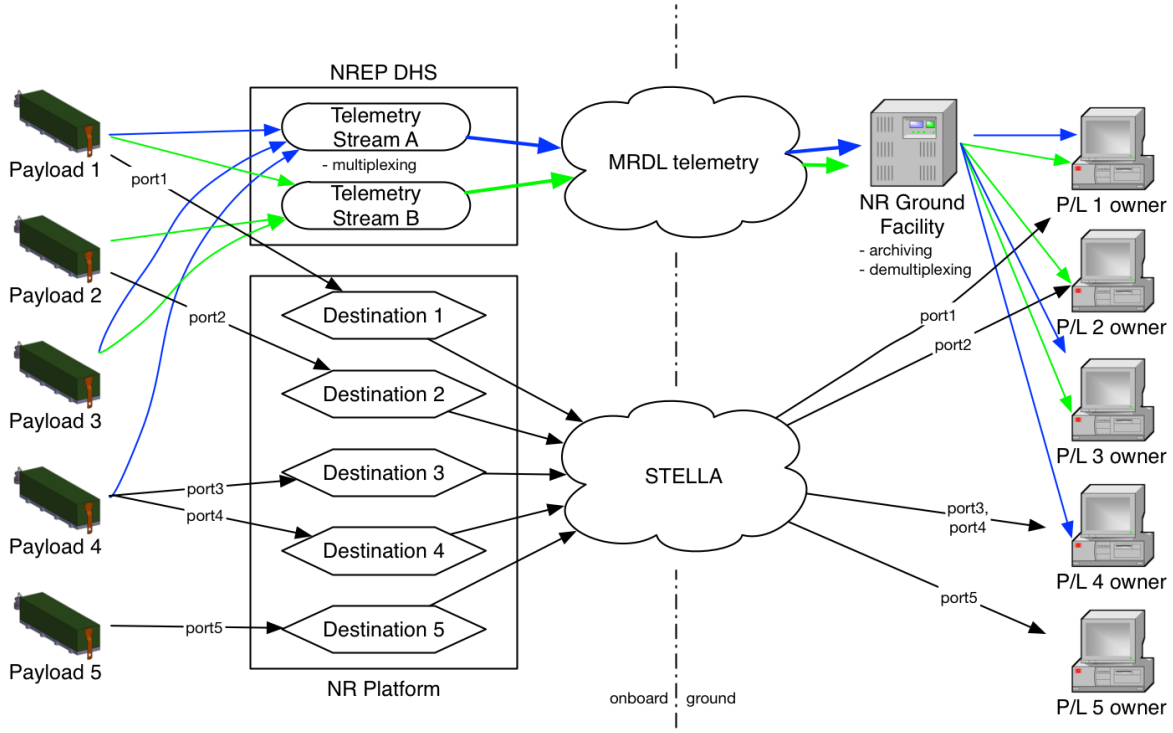

Figure 11-2: Data Streaming Example

In this example, payloads 1, 3, and 4 are sending data through the multiplexed telemetry stream A on the NREP DHS. Payloads 1, 2, and 3 are sending data through stream B. Both telemetry streams are de-multiplexed by the NanoRacks Ground Facility and forwarded to the payload owners. The NanoRacks Ground Facility will also archive telemetry streams.

Payload 1 is also sending UDP packets through STELLA to a receiving port at payload 1's owner (requires a matching STELLA configuration on-board and on the ground, see next section). Payloads 2, 4, and 5 are also sending UDP packets to their owners via STELLA. Due to STELLA restrictions, port numbers for each UDP destination must be distinct (i.e., coordination required).

Each payload may be configured to use up to 4 streaming destinations (in the example, payloads 1 and 4 are using 3, payloads 2 and 3 are using 2, and payload 5 is using only one). Data streaming in any form requires payloads that are capable of using IP networking over USB (see 11.2.1.2).

The bandwidth is limited by the available MRDL bandwidth for NREP, which is shared by Telemetry Streams A and B, and the MRDL bandwidth of the NanoRacks Platform, which is shared by the STELLA streams (i.e., planning and coordination are required). Payloads can be commanded to turn data streams on/off separately.

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11.1.2 Emulated Network Communication Using STELLA

Currently, the ISS communication systems don't provide seamless direct IP networking between the ground and ISS payloads. Certain point-to-point communications using IP based protocols can be emulated by using the STELLA software (RD 2.2.12).

STELLA does not provide general-purpose network connectivity, and also no routing capabilities; one limiting factor is the extremely asymmetric bandwidth available for downlink (500-600 kbps) vs. uplink (a single 800 bit packet per second), which would break most traditional IP based protocols, notably TCP.

STELLA does provide a number of communication services to the payload operator, which are described in the following sections:

- a console service that allows remote login to a STELLA host on orbit,
- a file transfer service for up- and downloading files to and from an on-orbit STELLA host,
- and a packet forwarding service mainly for unidirectional UDP transfers (with fixed destination host/port settings that must be statically pre-configured in the STELLA configuration file),

In order to use STELLA via the STELLA ground endpoint at the NanoRacks ground facility, as shown in Figure 11-1, a payload operator needs to install front-ends of the STELLA software, and coordinate with NanoRacks regarding the correct configuration of the STELLA endpoints at the ground facility and on the NanoRacks platform on orbit.

Future enhancements of NASA's ISS communication infrastructure ("KU-Forward") will allow direct IP networking between the ground and onboard payloads, ultimately making STELLA obsolete. (Exact time frame, routing capabilities, and usage constraints TBD; projected availability is 2015.)

11.1.2.1 STELLA Console Service; Payload Commanding

Using the STELLA console service installed on their operator PC, payload operators are able to acquire a command line on the NanoRacks platform. From there, they can perform a remote login to the NREP DHS, with the capability to send simple commands to their payload and request its current status, by means of an ASCII-terminal-like interface, including a status line/status description (see Figure 11-3).

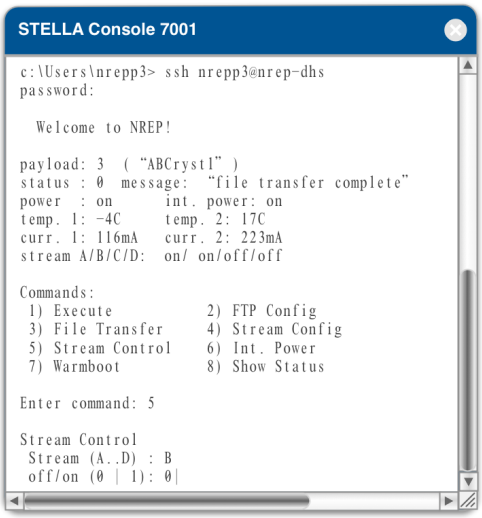
STELLA Console 7001
c:\Users\nrepp3> ssh nrepp3@nrep-dhs
password:
Welcome to NREP!
payload: 3 ("ABCrystl")
status : 0 message: "file transfer complete"
power : on int. power: on
temp. 1: -4C temp. 2: 17C
curr. 1: 116mA curr. 2: 223mA
stream A/B/C/D: on/ on/off/off
Commands:
1) Execute 2) FTP Config
3) File Transfer 4) Stream Config
5) Stream Control 6) Int. Power
7) Warmboot 8) Show Status
Enter command: 5
Stream Control
Stream (A..D) : B
off/on (0 | 1): 0|

Figure 11-3: Commanding via STELLA Console

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Once logged in to the NREP DHS, payload owners will be presented with a menu of the following commands, mirroring the standard NREP operator commands (RD 2.2.11), but restricted to their own payload:

11.1.2.1.1 Payload Execute

This command sends a single command line to the payload. The interpretation of the command line is up to the payload itself.

Parameters:

Command	the command line to be sent

11.1.2.1.2 Payload FTP Configuration

This command configures access to an FTP server (e.g., on the NanoRacks Platform), to be used for file transfers.

Parameters:

Username	login user name
Password	login password
Server Address	IP address (xxx.xxx.xxx.xxx) of the FTP server
Server Port	port number to be used for FTP
Server Folder	folder pathname on the server

11.1.2.1.3 Payload File Transfer

This command initiates a file transfer to/from the payload.

Parameters:

Direction	to or from payload
Mode	either to/from DHS via USB Serial or to/from a preconfigured FTP server
Server Address	IP address (xxx.xxx.xxx.xxx) of the FTP server (if applicable)
Filename	name of the file to be transferred

11.1.2.1.4 Payload Stream Configuration

This command configures which data streams the payload is going to be using.

The actual streaming won't be turned on until commanded on using the Stream Control command.

Parameters:

Data format	A...D
Protocol	0 = UDP unicast, others TBD/payload dependent
Destination ID	telemetry A or B, or IP addressed stream 1…5 (see 11.1.1.3), or zero to disable this format

Note: The stream destinations, as shown in Figure 11-2, are considered a global resource shared by all payloads, and are configured by NREP operators based on agreement with the payload owner(s), and consistent with the static STELLA configuration. The Payload Stream Configuration shown here only picks from the configured destinations, for a particular payload.

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11.1.2.1.5 Payload Stream Control

This command allows to turn a previously configured payload data stream on or off (default is required to be off).

Parameters:

Data format	A...D
Off/On	turn the given stream (format) OFF or ON
Data Rate	in kB/sec; this is only a hint to the payload and not enforced by NREP.

11.1.2.1.6 Payload Internal Power

This command controls the optional internal 28 VDC power switch (if present).

Parameters:

Off/On	selection of OFF and ON

11.1.2.1.7 Payload Warmboot

This command instructs the payload to perform a warm boot.

Parameters:

OnOff	selection of OFF and ON

11.1.2.1.8 Payload Status Request

Reports the current status of the payload, as far as it is know to the NREP DHS.

Parameters:

None.

11.1.2.2 STELLA File Transfer Service

Using the STELLA file transfer tool installed on their operator PC, payload operators are able to transfer files to and from the NanoRacks platform on the ISS. From there, several mechanisms can be used to transfer files to and from an individual payload, in a separate step.

See section 11.1.1.2 for an overview.

As stated before, due to STELLA's uplink bandwidth limitations, the traditional C&DH file uplink path (11.1.1) may be preferable for file uplinks.

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11.1.2.3 STELLA IP Packet Forwarding

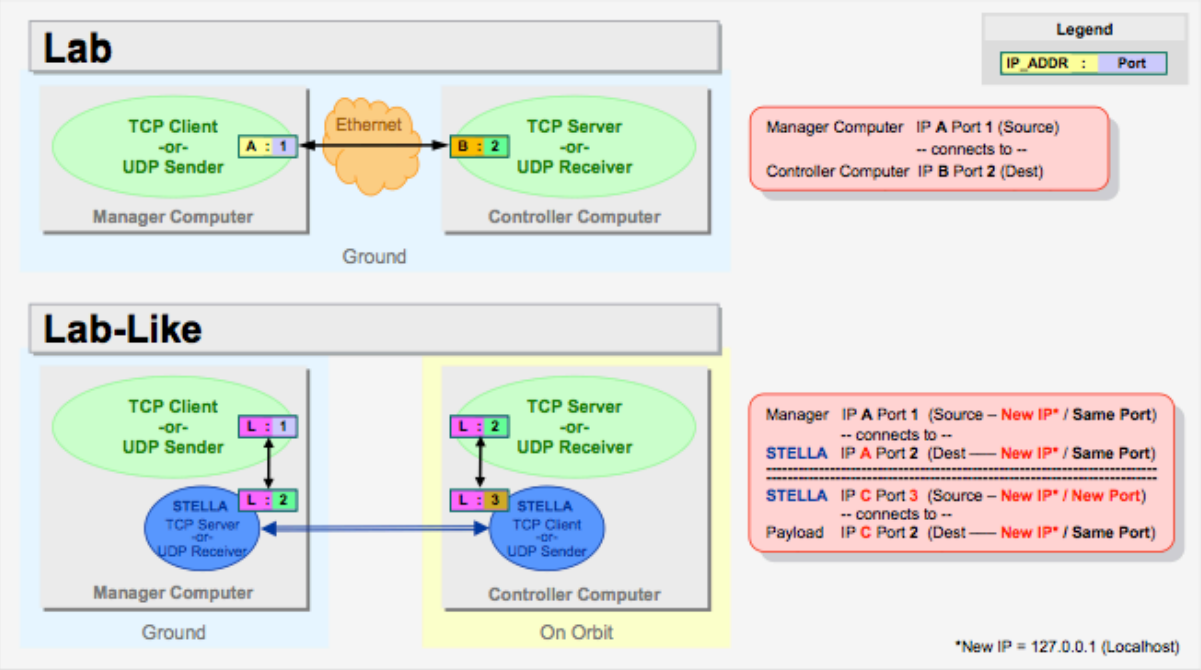

Figure 11-4: STELLA "Lab-Like" Communication

As shown in Figure 11-4 (from the STELLA User's Guide, RD 2.2.12), limited direct data transfer from a network-enabled payload to the payload operator via UDP packets is possible (switch "UDP Sender" and "UDP Receiver" in the figure), but needs to be preconfigured, by host address and port, in the STELLA configuration files both on the ground at the NanoRacks ground facility and on orbit on the NanoRacks platform. The packet size is limited to 1240 bytes, and each configured UDP link is unidirectional. Emulated "TCP" connections lose the TCP reliability feature, making them unusable for well-known TCP protocols (e.g., FTP, ssh).

Using STELLA for UDP uplink data transfers (as shown in the figure) is theoretically possible, but discouraged due to the extremely narrow uplink bandwidth.

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11.2 NREP DHS to Payload Software Interface Overview

This section describes the software interface between the NREP DHS and the NREP-P payloads.

Adherence to the required and optional interfaces described here is essential for the successful and safe operation of NREP payloads in space. It will ensure that an optimal amount of scientific as well as operational data from a payload can be made available to its owner.

An NREP internal payload is connected to the NREP Data Handling System (DHS) via a USB port, where the DHS is the USB host, and the internal payload is the USB client. The NREP DHS supports USB 2.0, with backward compatibility for USB 1.1 devices. All connected USB 2.0 devices share the theoretical USB 2.0 bandwidth of 480 kbps; i.e., if more than one USB 2.0 device is connected, the full USB 2.0 bandwidth will not be available.

As long as the payload's 28 VDC power is not applied to a payload, the payload is also not allowed to draw 5 VDC power on its USB port (see sect. 6.2.3). It should be in a completely passive state, and should not show any activity on the USB port.

Once the 28 VDC power is applied, as the payload starts up, it will advertise its device class(es) over the USB port, so that the communication between the NREP and the payload can begin.

To accommodate payloads with a wide range of capabilities and computing resources, from simple microcontrollers to more complex networking-capable payload controllers, the NREP DHS supports USB device classes of varying complexity.

In the simplest case, an internal payload only has to implement a very basic RS-232 style serial communication protocol over USB, to receive simple commands from the DHS and return simple status messages.

Payloads with more advanced internal computing capabilities will be able to use TCP/IP networking over USB, for which the NREP DHS provides automatic network configuration by DHCP, NTP for time synchronization, FTP for file transfer, and telemetry streaming options.

A payload may also advertise itself as a USB mass storage device for (limited) data transfer.

11.2.1 USB Device Classes

An internal payload may implement the listed device classes. Other device classes are discouraged and will be ignored by the NREP. Internal payloads may be implemented as one single-function or multifunction device, or they may include USB hubs serving multiple physical devices.

11.2.1.1 CDC Abstract Control Model (Serial Communication)

For basic commanding and monitoring, an internal payload is required to implement a USB serial communications device (CDC Abstract Control Model subclass, see RD 2.2.2).

The NREP DHS will use the resulting virtual serial port for sending commands to and receiving status messages from the payload (see sect. 11.3.1 for details).

The serial port configuration will be set to 57,600 bd, with 8 data bits, no parity, and 1 stop bit.

Upon connection to this device class, the NREP DHS will establish a serial communication channel to the internal payload, which is maintained as long as the payload is powered. For commanding and status collection purposes, each internal payload is required to provide one and only one CDC ACM device.

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11.2.1.2 CDC Ethernet Control Model (Networking)

Optionally, an internal payload may implement a networking device (CDC Ethernet Control Model subclass, see RD 2.2.3). A payload implementing this device class must configure its network interface in compliance with settings defined in the NREP-P ICA. The provided router address will be the internal subnet interface of the NREP DHS, which is also the host address for DHS services (telemetry, sect. 11.3.4, and network time, sect. 11.3.5).

Each payload may connect up to 5 internal networking devices, each of which will receive a predefined IP address on a separate subnet. All payload networking devices can communicate with each other as well as with external hosts (e.g., for file transfer or data streaming), using the NREP DHS as their default router.

On the NREP DHS side, the CDC ECM communication is handled by the Linux usbnet framework (RD 2.2.5), which is also recommended for internal payload controllers based on Linux 2.6 or later.

11.2.1.3 Mass Storage Device Class

[NREP DHS Release 2 capability]

Optionally, an internal payload may implement the Mass Storage device class (see RD 2.2.4).

Upon connection of a Mass Storage Device with a supported file system type, the NREP DHS will mount the file system as an external drive. Supported file system types are Fat16, Fat32, ext2fs, ext3fs, and TBD others.

Note that while a Mass Storage Device is mounted by the NREP DHS, the payload is not allowed to modify the content of the provided file system in any way. *Only the NREP DHS is allowed to write to a mounted file system*. For this reason, using the Mass Storage Device class for an internal payload is only of limited value, as there is no way of un-mounting in a controlled way.

The handling of mounted Mass Storage Device file systems by the NREP DHS (e.g., mount points, pathnames) is TBD.

11.3 NREP DHS Payload Services

11.3.1 Commanding

The NREP DHS provides the capability to send commands to an internal payload. Most commands originate from commands that the payload operator on the ground sends to the NREP DHS via ISS commanding channels (operator commands). Only the Status command (11.3.1.1) is sent autonomously by the NREP DHS to request the current status of an internal payload.

The serial communication channel (sect. 11.2.1.1), which is mandatory for all internal payloads, is used to send commands to the internal payload. The communication is always initiated by the NREP DHS by sending an ASCII <ESC> (0x1B) character, which is used for synchronization; i.e., the payload is expected to discard any characters received before the first <ESC> character. The <ESC> character is followed by a command consisting of a single command character, followed by command parameters as described below. Each command ends with an ASCII <LF> (0x0A) character.

For the Status command (11.3.1.1), a status response in a defined format is expected; for all other commands (operator commands), the payload is expected to send either one of the following:

`OK`[`:`<description>]<LF> *in case of successful execution*

`NOK`[`:`<description>]<LF> *in case of unsuccessful execution*

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It is strongly recommended to provide a <description> string, in particular for negative responses. If an optional[1] <description> string, separated by a colon (‘**:**’), is provided, it will be echoed in the Health & Status payload status message field (up to 32 characters, see 11.3.2; i.e., any response characters past the 36th character will be discarded).

An ASCII <LF> (0x0A) character delimits the payload response.

In general, the DHS to payload communication is synchronous. The DHS will not send another command until a response from the payload has been received. Payload responses are, however, expected to be received completely (including the terminating <LF>) within 5 seconds; otherwise, the NREP DHS will time out and report an error. Therefore, potentially time consuming operations should be acknowledged first and then executed asynchronously; the completion of an asynchronous operation and its success or failure may be reported in the payload’s status message in response to the Status command.

When a payload receives an <ESC> character before sending its own response, it has to assume that a timeout has occurred, and should suppress its not yet transmitted response in order to re-synchronize with the DHS.

A deviation from the synchronous command/response pattern is possible during a Transmit operation over the serial connection (11.3.1.4), to allow the DHS to abort a file transfer.

11.3.1.1 S: Status Command

Description

The status command is sent periodically (nominally once per second) by the NREP DHS to collect status information from each internal payload. Status data collected by the Status command will be reported in the NREP Health & Status (H&S) data (sect. 11.3.2).

Additionally, the Status command is time-tagged, to allow an internal payload to synchronize its own time base with the NREP DHS system time (see also sect. 11.3.5).

Syntax

S<timestamp><LF>

<timestamp> extended ISO 8601 format with UTC timezone and second fraction (see 11.3.5 for an example); reflects the current DHS system time at the moment that the Status command is sent.

Payload Response

The internal payload responds with a ASCII status string of the following syntax:

<payload-ID>**:**[<temp-1>]**:**[<temp-2>]**:**[<current-1>]**:**[<current-2>]**:**<status-code>**:**[<status-msg>]<LF>

with the following field definitions:

[1] In the syntax descriptions, square brackets [… *optional* …] enclose optional parts.

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<payload-ID>	a string of up to 8 characters identifying the payload (not containing a colon)
<temp-[1|2]>	temperature measurements in °C in the range [-128..127] (integer)
<current-[1|2}>	electrical current measurements in mA in the range [0..65535] (integer) *(Note: the actual maximum sustained current per payload is 2 A.)*
<status-code>	payload specific status code, range [2..255] (integer; 0 and 1 are reserved)
<status-msg>	free-form message string extending from the 6th colon to the terminating <LF>; up to 32 characters

All numeric fields shall be represented without blanks or leading zeros, to keep the response length to a minimum. Hence, the maximum useful response length will be 67 characters. Excessive responses may be truncated by the DHS.

Empty strings between colons denote measurements that are not provided by the payload (in general or temporarily). The last known value for not provided measurements, if any, will continue to be reported in the NREP H&S data; the initial value for all fields is zero.

Status code and status message are payload specific and not interpreted by the DHS, only reported.

The status message included in the payload H&S data (11.3.2) is shared by Status command responses and operator command responses (any string returned with an `OK` or `NOK` response). It will be updated only whenever a non-empty status message is received from the payload; otherwise, the last received message will be retained in H&S. Since the Status command is sent once per second and might overwrite a previous message, such as an operator command response, it is suggested to normally return an empty <status-msg> unless a noteworthy event occurs, such as the completion of an asynchronous operation. This will allow the operator more time to read a previous command response.

Example

```
ABCrystl:-4:12:1560::2:file transfer complete<LF>
```

Meaning:

<payload-ID>	ABCrystl
<temperature-1>	–4 °C
<temperature-2>	+12 °C
<current-1>	1560 mA
<current-2>	*(not provided by payload)*
<status-code>	2 *(payload specific – 2 could mean "success")*
<status-msg>	"file transfer complete"

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11.3.1.2 N/O: Internal Power Commands

Description

A payload may contain an optional internal switch to control the 28 VDC power to its experiment equipment (see Figure 6-1). The Internal Power commands are used to control this internal switch, if available.

For a payload that does not contain the optional switch, the payload response should be NOK.

Syntax

N<LF> turn on internal 28 VDC power switch

O<LF> turn off internal 28 VDC power switch

Payload Response

OK[:<description>] power switching successful

NOK[:<description>] power switching failed

11.3.1.3 W: Warmboot Command

Description

Upon receipt of the Warmboot command, the payload is expected to reset/reinitialize itself to a defined, initialized state (details are up to the payload).

Syntax

W<LF>

Payload Response

OK[:<description>] Warmboot command received, reset about to occur

NOK[:<description>] Warmboot command rejected (a reason should be given)

After an OK, the payload should perform a reset/re-initialization, during which the serial connection may drop. Disconnection and re-connection will be reflected in H&S data.

11.3.1.4 T: Transmit File Command

Description

The Transmit File command instructs the payload to transmit a specified file to the NREP DHS through the serial connection, using the Intel HEX format (RD 2.2.6).

Syntax

T<filename><LF> command the payload to transmit the file named <filename>

Payload Response

Upon receipt of the Transmit File command, if the request cannot be satisfied (e.g., file not found, or feature not supported), the payload responds NOK[:<description>].

Otherwise, the payload starts sending the file content across the serial connection using the Intel HEX format.

At any point during the transmission, the DHS may send an Abort command (11.3.1.9), upon which the payload should end the transmission.

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After the file transfer finishes (either normally or aborted), the payload outputs a final OK[:<description>] or NOK[:<description>] message.

At any point during the transmission, up to and including the final OK/NOK, the DHS will consider the transmission failed after a 5 second period of inactivity of the payload.

See sect. 11.3.3 for general file transfer considerations.

11.3.1.5 R: Receive File Command

Description

The Receive File command instructs the payload to receive a specified file from the NREP DHS through the serial connection, using the Intel HEX format (RD 2.2.6).

Syntax

R<filename><LF> command the payload to receive the file named <filename>

Payload Response

After sending the Receive File command, the NREP DHS will start sending the file content across the serial connection using the Intel HEX format.

At any point during the transmission, the payload may send NOK[:<reason>] if it encounters a problem (invalid file path name, not enough space, feature not supported), upon which the NREP DHS will abort the file transfer and report the error condition. In such a case, it is recommended that the payload provide a <reason> for the NOK.

Upon receiving an abort command from the ground operator during an ongoing file transfer, the DHS may abort the transfer by sending the Abort command (11.3.1.9) to the payload instead of the next line of the Intel HEX protocol. In this case, the payload should abort the receiving process and discard or disregard the partially transferred file.

After the file transfer finishes (either normally or aborted), the payload reports overall success and/or failure by responding OK or NOK[:<reason>], which is then reported by the NREP DHS.

If the final OK/NOK is not received from the payload within 5 seconds of the end-of-file record, the DHS will consider the transmission failed.

See sect. 11.3.3 for general file transfer considerations.

11.3.1.6 P/G: FTP File Transfer Commands

Description

The FTP File Transfer command instructs a payload that supports a USB network interface (see 11.2.1.2) to perform a file transfer to/from a specified server using the FTP protocol.

Syntax

Instruct payload to perform an FTP “get” operation:

G<server-address>:<port-number>:<username>:<password>:<folder>:<filename><LF>

Instruct payload to perform an FTP “put” operation:

P<server-address>:<port-number>:<username>:<password>:<folder>:<filename><LF>

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Parameters for both commands:

<server-address>	IPv4 address of an FTP server
<port-number>	the port number to be used for FTP
<username>	the user name to be used for logging into the FTP server
<password>	the password to be used for logging into the FTP server
<folder>	target directory name (potentially an empty string) on the FTP server
<filename>	the file/pathname to be used on the payload

Payload Response

The internal payload acknowledges receipt of the command (not completion) by responding `OK` or `NOK[:<reason>]` (e.g., unsupported feature). If the response was `OK`, the payload is expected to initiate the actual file transfer asynchronously and report the final success or failure to the operator in the payload status message (in response to the Status command, 11.3.1.1).

The NREP DHS does not monitor the progress and finalization of FTP transfers by the payload.

If the ground operator, via the DHS, sends an Abort command (11.3.1.9) while an FTP transfer is still ongoing, the payload should abort the FTP transfer.

See sect. 11.3.3 for general file transfer considerations.

11.3.1.7 `D`: Data Streaming Command

Description

The Data Streaming command informs a payload that supports a USB network interface (see 11.2.1.2) of a server, port, and protocol to be used for data streaming.

Up to 4 data streams, identified by a <format-ID>, are supported per payload, which can be controlled separately. If only the <format-ID> is given, followed directly by <LF>, the payload must stop the specified data stream.

The <data-rate> in kB/s, if present, is currently only a hint to the internal payload, and not enforced by the DHS.

See also sect. 11.3.4 on payload telemetry data.

Syntax

`D`<format-ID>[`:`<server-address>`:`<port-number>`:`<protocol>[`:`<data-rate>]]<LF>

<format-ID>	single letter ['A'..'D'] identifying one of up to 4 data streams
<server-address>	IPv4 address of the stream destination host
<port-number>	port number on the destination host
<protocol>	[0..15] stream protocol (0 = UDP; others payload specific)[2]
<data-rate>	data rate in kB/s

Payload Response

The internal payload acknowledges receipt of the command (not completion) by responding `OK` or `NOK[:<reason>]` (e.g., unsupported feature), which will be reported by the NREP DHS.

[2] If the data stream is destined for the multiplexed MRDL telemetry streams offered by the DHS (see sect. 11.1.1.3), the protocol has to be UDP.

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11.3.1.8 X: Execute Command

Description

The Execute command may be used to pass a command string directly to a payload. Interpretation and execution of the command string are the sole responsibility of the payload.

Syntax

X<command-string><LF>

<command-string> command string to be interpreted by the payload (up to 100 ASCII characters)

Payload Response

The internal payload responds OK or NOK[:<reason>] based on its interpretation/execution of the given command. In the case of NOK, the payload should provide a <reason> that will be reported by the NREP DHS.

Since the NREP DHS expects a response (either OK or NOK) within 5 seconds, payload commands that require a longer period of time should be executed asynchronously; in this case, an OK response would only acknowledge receipt/acceptance of the command, a NOK response would indicate immediate rejection of the command; final success/failure should be reported in the payload status message (11.3.1.1).

If the payload receives an Abort command (11.3.1.9) while executing an Execute command asynchronously, it may, but is not required to, abort that execution.

11.3.1.9 A: Abort Command

Description

The Abort command is sent to abort a previously commanded asynchronous operation, such as an FTP file transfer (11.3.1.6) or an operation started by an Execute command (11.3.1.8).

Syntax

A<LF>

Payload Response

The internal payload responds OK or NOK[:<reason>] based on its interpretation/execution of the given command. In the case of NOK, the payload should provide a <reason> that will be reported by the NREP DHS.

If no asynchronous operation was pending (any more), the payload may simply respond OK.

If two or more asynchronous operations were pending, the reaction of the payload is up to the payload (e.g., abort the last one).

11.3.2 Health and Status Monitoring

The serial communication channel (sect. 11.2.1.1) is used periodically by the NREP DHS to query internal payloads for their internal status, by sending the Status command (sect. 11.3.1.1), at a nominal rate of once per second (except during the execution of other commands).

Additionally, the NREP DHS keeps track of payload configuration data that was submitted successfully to a payload (payload response "OK"), such as streaming data destinations.

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The following data items are monitored for each internal payload (1 through 5) and reported as part of the overall NREP Health and Status data:

Table 11-2: Internal Payload Health and Status Items

Data Item	Values	Length	Source	cf. sect.
ID String	payload ID string	8 bytes	PL status	11.3.1.1
Status String	payload status message	32 bytes	PL status	11.3.1.1
Status Code	payload status code (0: unconnected, 1: unknown, 2..255: payload specific)	8 bits	DHS/PL	11.3.1.1
Power Status	ext. 28 VDC on/off	1 bit	DHS	
Internal Power Status	int. 28 VDC off, on, or N/A	2 bits	DHS	11.3.1.2
Network I/F #1/2/3/4/5	up/down	1 bit each	DHS	11.2.1.2
28 VDC current	in mA	16 bits	DHS	
Internal current #1/2	in mA	16 bits each	PL	11.3.1.1
Internal temperature #1/2	in °C, range [-128..127]	8 bits signed each	PL	11.3.1.1
Downlink packet counter	number of network packets received	16 bits	DHS	11.2.1.2
Stream dest. A/B/C/D	configured destination index [1..5]	3 bits each	DHS	0/11.3.4
Stream status A/B/C/D	disabled/enabled	1 bit each	DHS	0/11.3.4

11.3.3 File Transfer

There are two ways to transfer files to/from an internal payload. The preferred way is to use the FTP protocol, if the payload supports networking over USB (sect. 11.2.1.2), because this allows a better data rate, increased flexibility, and a reduced number of steps to perform a file transfer end-to-end, compared to the fallback solution of transferring files over the USB serial connection (sect. 11.2.1.1).

For files transferred between a payload and the NREP DHS, either over the serial connection or by FTP to/from the FTP server provided by the DHS itself, there are multiple uplink and downlink paths from/to the ground, which are described in the NREP User Manual (RD 2.2.10).

11.3.3.1 FTP File Transfers

An internal payload that supports networking over USB can be commanded to perform a file transfer via the FTP protocol (RD 2.2.8). Any reachable FTP server may be used as a source and/or destination, including the NanoRacks platforms in the EXPRESS racks onboard the ISS, from/to where they can be further transported, e.g., to/from the ground, as needed, or the FTP server provided by the NREP DHS itself.

11.3.3.2 File Transfer via Serial Connection

Using the Transmit and Receive commands, files can be transferred between a payload and the NREP DHS. In this case, the NREP DHS is used as an intermediary, and additional steps will be needed to transfer a file between the DHS and its original source resp. final destination.

Due to the relatively low baud rate of the serial connection and the overhead of the Intel HEX format, the user data transfer rate is limited to about 2 kB/s; therefore, serial file transfer should be limited to small files. Also, consider that while the serial connection is in use by a file transfer, status monitoring for that payload is suspended, which creates a gap in payload monitoring data.

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11.3.4 Telemetry

For internal payloads that implement IP over USB networking (11.2.1.2), the NREP DHS provides two UDP ports to which payloads may direct UDP packets. The DHS will extract the data portion of each received UDP packet and wrap it in one or more CCSDS packets that will be sent directly to the ground via Medium-Rate Data Link (MRDL) telemetry.

Packets from different payloads sent to the same port will be multiplexed into a single telemetry stream, with the payload number, derived from the source IP address, encoded in the "Version ID" field of the CCSDS packet header, allowing for de-multiplexing of the data streams per payload on the ground. Each of the two DHS telemetry ports corresponds to a separate telemetry stream, distinguished by the "APID" field in the CCSDS header. Forwarding the de-multiplexed telemetry stream to payload operators in real time is possible and may be provided in the future (requiring software processing at the NanoRacks ground facility).

Due to MRDL limitations, the maximum user data length per CCSDS packet is limited to 1484 bytes. Payload data packets with user data up to that length will be repackaged into a single CCSDS packet; larger user data packets will have to be fragmented by the NREP DHS into consecutive CCSDS packets (not supported in V1.0 of the DHS software; may be supported in later versions). Therefore, it is recommended not to exceed a user data length of 1484 bytes if a one-to-one correspondence is desired between sent payload packets and packets received on the ground (e.g., to preserve a fixed packet structure).

11.3.5 System Time

The NREP DHS receives the current time (UTC) from the ISS onboard system. It synchronizes its own system time with the ISS onboard time.

As a service to internal payloads, the NREP DHS uses two ways to communicate the current time:

1. The NREP DHS time-tags the Status command with the current time, in ISO 8601 extended format with time zone designation and comma-separated fraction of seconds (YYYY-MM-DDThh:mm:ss,ffffZ, RD 2.2.7; note the terminating 'Z' character, denoting the UTC time zone).
   Example: `2014-09-25T14:56:33,3468Z`
2. For payloads implementing networking over USB, the NREP DHS provides a Network Time Protocol (NTP) server at its address on the internal payload subnet (see 11.2.1.2 for the internal payload subnet; see RD 2.2.9 for NTP).

NTP time is generally preferable/more accurate, compared to the Status command time tag.

11.3.6 ISS Ancillary Data

[NREP DHS Release 2 capability]

The ISS onboard system makes available "ancillary data", including such information as location, velocity, or sunrise/sunset times.

The NREP DHS will provide ancillary data access to networking enabled internal payloads, using a TBD protocol implementing a publish/subscribe model of data items that an individual payload is interested in.

Certain types of ancillary data, such as upcoming times for Loss of Signal (LOS) and Acquisition of Signal (AOS) may also be reported as a service provided by the NanoRacks Ground Facility.

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Appendix A: Acronyms

A

ACK	acknowledgement
AD	Applicable Document
AOS	Acquisition of Signal
APID	Application Process Identifier
ASCII	American Standard Code for Information Interchange
AWG	American Wire Gauge

B

BOL	Beginning of Life

C

C&DH	Command and Data Handling
CCSDS	Consultative Committee for Space Data Systems
CDC	Communications Device Class
CPU	central processing unit

D

DHS	Data Handling System

E

EXPRESS	EXpedite the Processing of Experiments for Space Station

F

FTP	File Transfer Protocol

G

Geometric Math Model

H

H&S	Health and Status
HOSC	Huntsville Operations Support Center

I

ICA	Interface Control Agreement
ICD	Interface Control Document
IEEE	Institute of Electrical and Electronics Engineers
iPEHG	Improved Payload Ethernet Hub/Gateway
IP	Internet Protocol
IPv4	Internet Protocol, version 4
ISS	International Space Station

J

JEM	Japanese Experiment Module
JEM-EF	JEM Exposed Facility
JSC	Johnson Space Center
JSL	Joint Station LAN

L

LAN	Local-Area Network
LDP	Logical Data Path
LEHX	Layer 2 Ethernet Hub Multiplexer
LOS	Loss of Signal
LRDL	Low-Rate Data Link
LSB	least significant byte

M

MAC	Media Access Control
MD5	Message Digest 5 algorithm
MIUL	Material Identification Usage List
MRDL	Medium-Rate Data Link
MSB	most significant byte
MSFC	Marshall Space Flight Center

N

NREP	NanoRacks External Platform
NREP-P	NREP payload

P

PC	Personal Computer
PDL	Payload Data Library
PEHG	Payload Ethernet Hub/Gateway
PL, P/L	payload
POST	power-on self test
PSU	Power Supply Unit

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PTMM	Payload TMM

R

RAM	random-access memory
RD	Reference Document
Rx	receive

S

SI	Système international d'unités (International System of Units)
SIDD	Standard Interface Definition Document
ssh	secure shell
SSID	Service Set Identifier
STELLA	Software Toolkit for Ethernet Lab-Like Architecture
SW	Software

T

TLM	telemetry
TReK	Telescience Resource Kit
Tx	transmit

U

UDP	User Datagram Protocol
USB	Universal Serial Bus

V

VDC	Voltage of direct current

W

WiFi	“Wireless Fidelity” = Wireless LAN
WLAN	Wireless LAN

T

TBD	to be determined
TCP	Transmission Control Protocol
TMM	Thermal Mathematical Model

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Appendix B: Definitions

A

Application Process Identifier
: The APID is an 11 bit field within the primary header of the CCSDS packet, which identifies a particular source and destination for commands and telemetry packets (see also Logical Data Path).

B

Byte
: A byte is a set of bits representing a value and can vary in number of bits per set such as 4 bits per byte, 8 bits per byte, etc. The bytes referenced in this document are assumed to be 8 bits per byte (octet).

C

Consultative Committee for Space Data Systems
: CCSDS is an organization officially established by management of member space agencies for addressing data system problems with accompanying recommended technical solutions.

D

Data Packet
: A variable length, delimited data structure encapsulating sets of higher-layer user data within a standard header message.

L

Logical Data Path
: The Logical Data Path (LDP) is the path used for transferring user data between a known source and destination as derived from the APID table. The management between relay points in the link is predefined by configuration tables using the APID as a reference to select the proper path ID.

Low Rate Data Link
: LRDL refers to data packet communications over the MIL-STD-1553B data bus.

M

Medium Rate Data Link
: MRDL refers to data packet communications over the Ethernet Local Area Network within a packet of 100 to 1500 octets.

O

Octet
: A collection of 8 bits (byte).

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P

Payload Ethernet Hub/Gateway
: An Ethernet switched hub on board the ISS for routing IEEE 802.3 packets to/from appropriate I/O ports.

T

Telemetry
: A term used to characterize the generation of continuous and predictable sets of space mission measurement data, which have a large interaction with overall communications resources.

W

Word
: Words as used in this document are collections of 16 bits.

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